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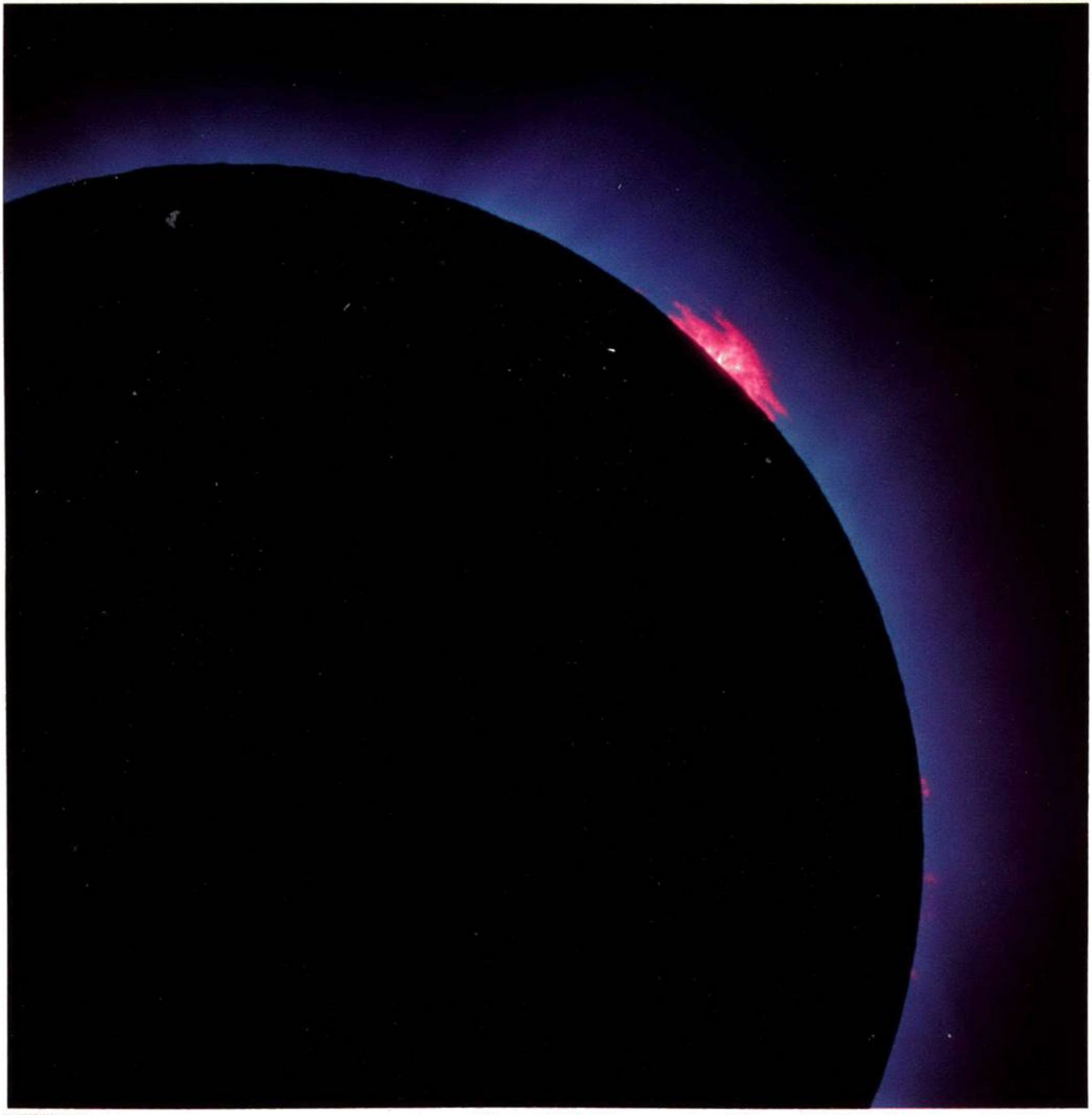

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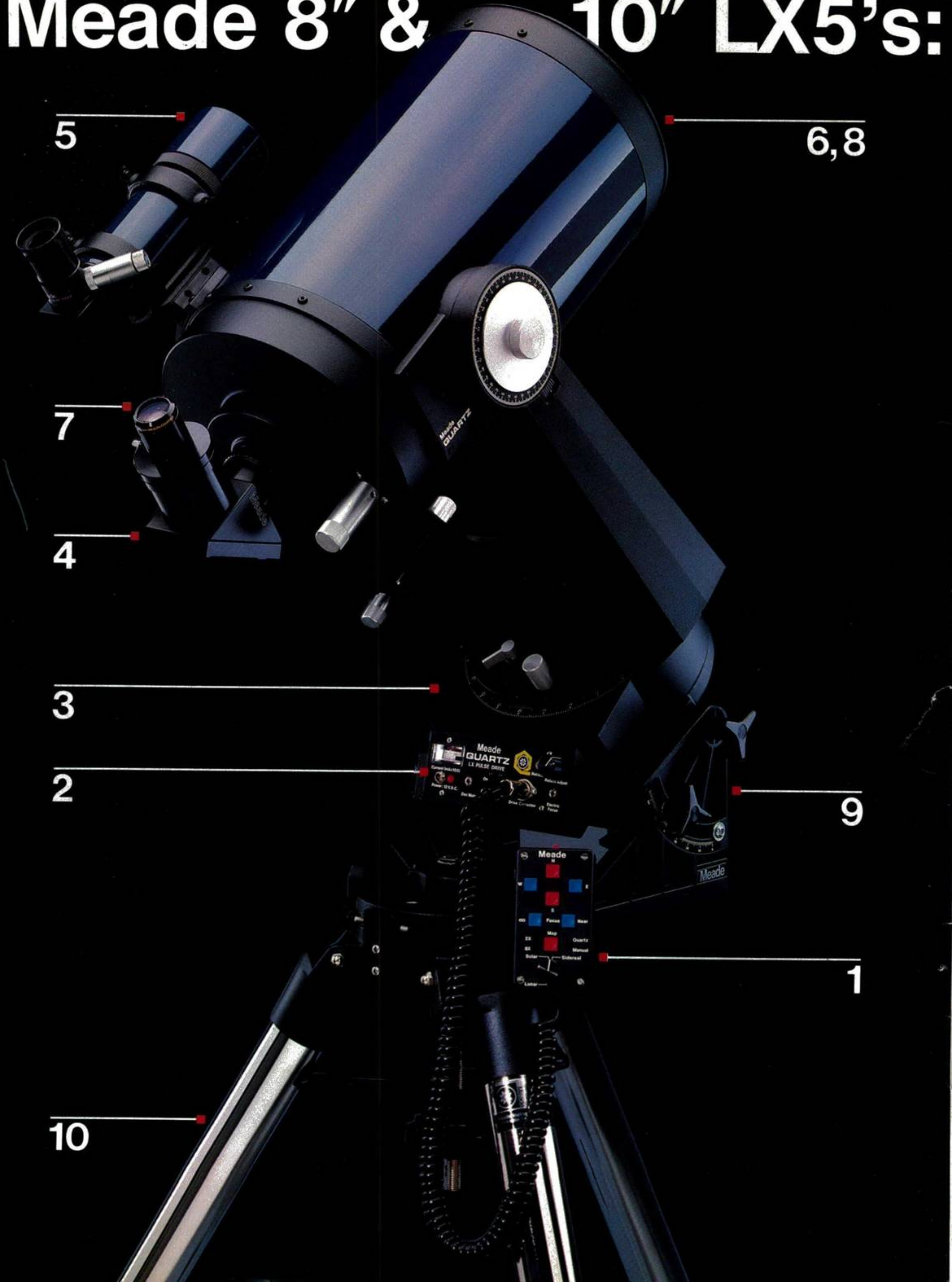
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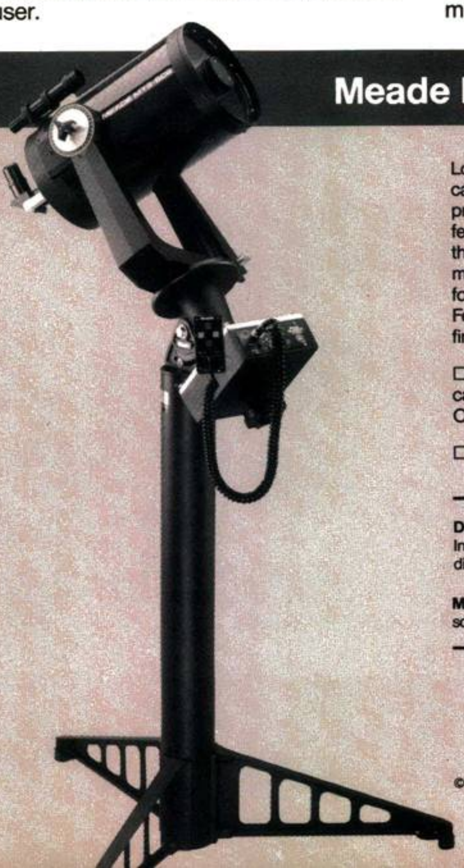

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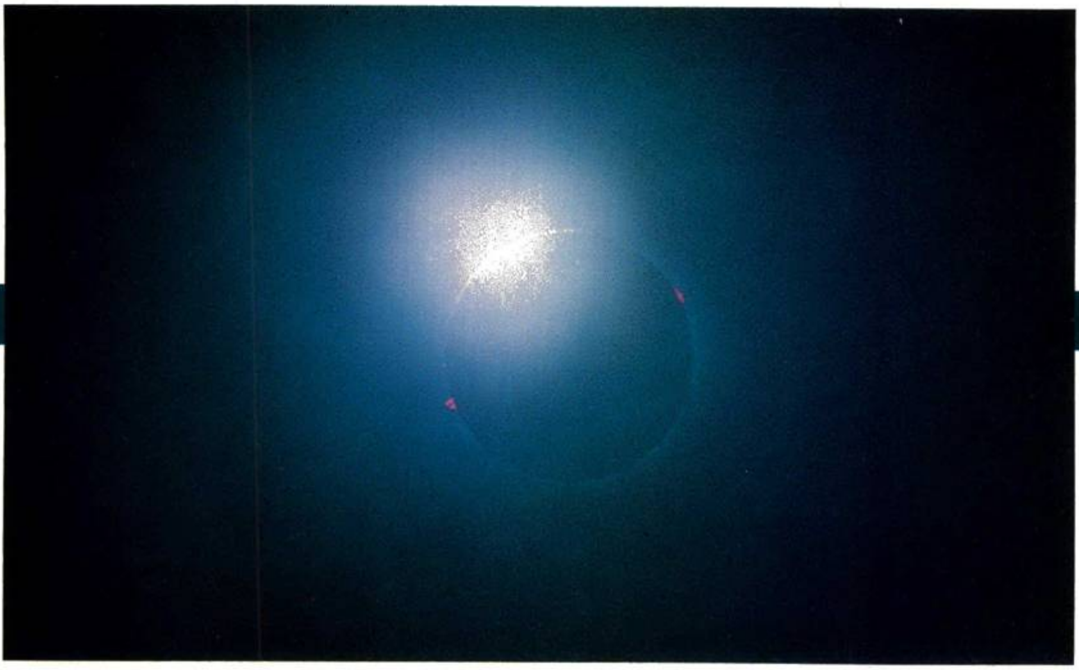
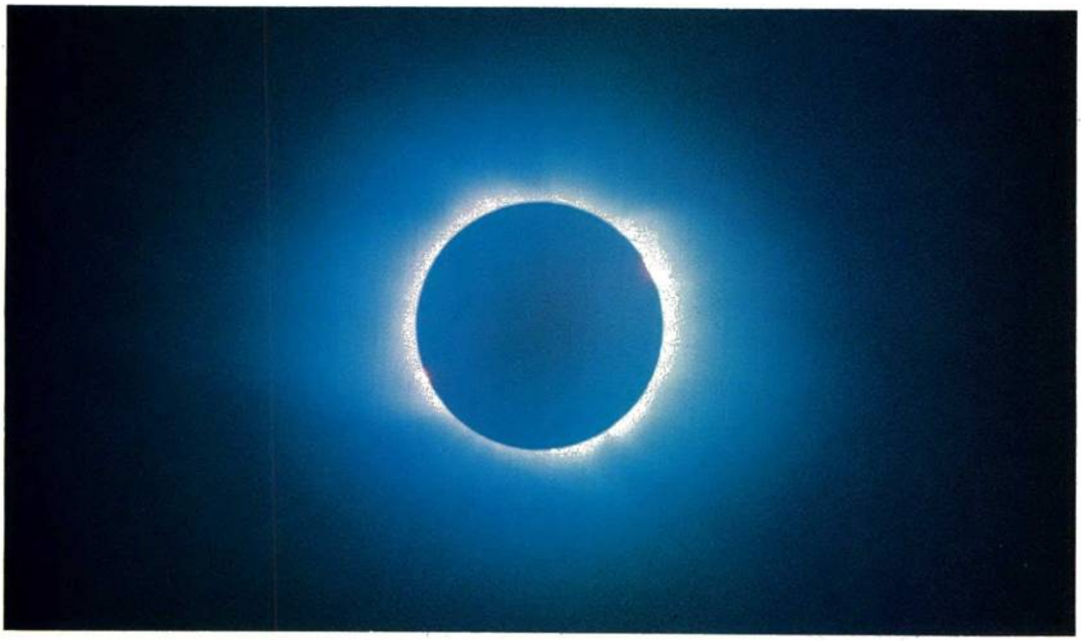


ON THE COVER: Shining crimson on the solar limb, huge prominences "wowed" Jacques Guertin, who traveled to the south Pacific to photograph the March 18 eclipse.



THREE STAGES — second contact, totality, and third contact — of the 1988 eclipse were captured by Huguette Guertin.

ASTRONOMY®

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From an ancient era of massive bombardments to the present day, encounters with solar system debris have left their marks on the planets. By Patricia Barnes-Svarney.

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Behind the Scenes

THE NEW LOOK OF ASTRONOMY

Welcome to the new ASTRONOMY.

In our newly designed magazine you'll find news stories toward the front, hobby articles in the back, and features in the middle. At every level, ASTRONOMY is clearly organized and easy for you to use.

As you can see, this column and Letters now open the magazine. In Viewpoint, a new column, prominent public figures will explain how the world of astronomy interacts with the everyday world.

In AstroNews you'll find two new sections — Space News and Amateur News, devoted to the latest developments in those areas — as well as reports on the findings of current research in astronomy.

Our feature articles will continue to explore significant new ideas about the cosmos, provide an in-depth understanding of astronomical phenomena, and relate astronomy to other human concerns. In addition, through the new ASTRONOMY you'll also meet the faces and personalities behind the data. You'll discover how astronomers think and what they think about.

We're proud of our new, expanded Sky Almanac. Located in the center of the magazine, these ten pages guide you through the changing panorama of the night sky. I'd also like to introduce our Sky Almanac columnists. With Deborah Byrd, known for her award-winning "Star Date" radio show, you'll enjoy naked-eye stargazing in Eye on the Sky. Rick Shaffer, accomplished telescope builder and observer, will keep you up to date on telescopic sky events in Through the Eyepiece.

Just beyond Sky Almanac on our tour of the new ASTRONOMY you'll find features to help you use astronomical equipment, carry out your own observing programs, and develop your observing skills.

As you look through the magazine, you'll see your old friends Forum, Astronomy Reviews (now called Astronomy Books), and AstroCalendar (now called Meetings and Events). For those of you who want to further explore topics presented in the magazine, we've added Readings and Resources, which provides suggestions for further reading and addresses of sources and suppliers, and Credits, with the complete technical information on all our photographs and illustrations.

If you liked the old ASTRONOMY, we hope you'll like the new ASTRONOMY even better. We think you will, because we've designed the new ASTRONOMY with you in mind.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

The Responsibilities of Exploration

In the interview with Robert M. Powers by A. J. Austin (Forum, April 1988) the terraforming of Mars was mentioned too casually.

Powers talked about artificially altering Mars' ice age to make the planet more like Earth. I say, not on your life. Laws should be passed now to prohibit altering the environments of the planets. How dare we think that we can push our way onto Martian soil and claim the planet in the name of mankind? We should leave this world alone until we can prove we can handle the responsibilities associated with exploration. — *James Moeller, Kirkville, New York*

Why Giordano Bruno Burned

Giordano Bruno was not the first person to propose the existence of extraterrestrial life, as stated in the interview with space writer Robert M. Powers. Instead it was Nicholas of Cusa, a fifteenth-century German theologian.

Bruno, a sixteenth-century Dominican friar, picked up on this idea, but it was not an "extremely dangerous idea" for the times, as Powers stated. The idea had been around for over a hundred years. However, Bruno practiced magic, thought that the stars and planets had souls, denied the deity of Jesus Christ, and thought the cross was a sacred Egyptian symbol. These ideas, not proposing that life exists on other planets, could get a man executed for heresy in the sixteenth century. — *Tom McMullen, Bloomington, Indiana*

Avoiding Planetary Contamination

"Let's Make Certain It's Dead" by Richard Berry (Behind the Scenes, April 1988) was a timely reminder of the need to avoid bringing microbes to Mars. Bringing Martian life to Earth could also have very serious consequences.

Though Mars is a hostile world, it could possibly have hot springs that make a reasonable environment for algae. Studies on the possible mode of formation of the small Martian channels show that ice-covered pools or streams fed by hot springs are possible even with the present thin atmosphere of Mars.

There may not be enough hot springs to support life on Mars, though Martian microbes may be able to survive extremely prolonged periods of dormancy. However, contamination could still occur if we landed at a time when hot springs were active. — *Frank Grober, Ridgecrest, California*

A Manifest Extraterrestrial Destiny

Leif Pierson's response (Letters, April 1988) to Frank Apsi-Ridolfo's "The Primal

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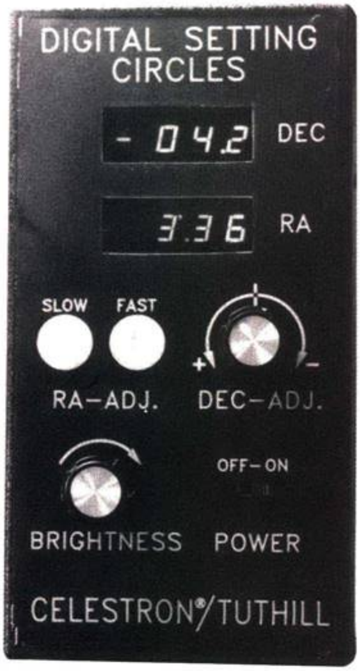
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Fear: Are We Alone?" (Forum, December 1987) doesn't solve the riddle for me. Pierson said he believes man was created for a purpose. But why should that preclude the search for other life in the universe?

I agree with Mr. Apsi-Ridolfo. With hope and humility we can look for a purpose *and* pursue our quest for other life. — *Donald R. Thompson, Madison, Wisconsin*

Keeping Sidereal Time by Computer

Faced with the need to keep sidereal time, as Irwin Sternberg was ("Build ASTRONOMY's Star Time Clock," March 1988), I elected to do my engineering from a keyboard rather than with a soldering iron and wrote a computer program to keep true sidereal time.

Because I owe a considerable debt to many others who made their source code available through public domain software over the past decade or two, my sidereal program, called ASTROCLK, is free for noncommercial use. The program with documentation and source code is available on a bulletin board system I maintain. The number is (213) 521-7299.

Individuals without a modem can obtain a disk containing the same files by sending me $5 to cover postage and handling. — *David H. Ransom, Jr., 7130 Avenida Altisima, Rancho Palos Verdes, CA 90274*

Religion Hand in Hand with Science

No wonder Father Royer has an avocation like astrophotography ("The Real Lives of Ten Top Astrophotographers," Forum, March 1988). I am an Episcopal priest serving one hundred families, and I can well understand Father Royer's need to withdraw from 2,700 parishioners upon occasion.

I too am a photographer on my day off, and I specialize in wildlife photography.

I also agree with Father Royer that creation and evolution are not necessarily antithetical. Properly understood, religion and science, or faith and reason, have always feasted convivially at the same banquet. It's only when one or the other dislikes what is being served that acrimony spoils the occasion. As in so many areas of life, it is hardly ever a matter of either/or but rather of both/and. — *Rev. Walter D. Clark, Rockport, Texas*

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity.

Viewpoint

U.S. ASTRONOMY LOSING GROUND

by Peter B. Boyce
Executive Director of the American Astronomical Society, the association representing America's four thousand astronomers

The United States has built an astronomical research structure that has been foremost in the world. The achievements of our astronomers have provided highly visible evidence of America's scientific and technological leadership.

Our instruments are superb. The twenty-seven antennas of the Very Large Array radio telescope provide the finest images of the radio sky. Our CCD camera chip detectors enable 30-inch telescopes to be as effective as the 200-inch telescope on Palomar Mountain was fifteen years ago.

With these ground-based instruments astronomers have pushed back the boundaries of our knowledge of the universe. But this resoundingly successful research structure is now threatened by eroding federal support for astronomical research.

At a time when observing requests at major U.S. telescopes exceed the available time by factors of three or four, the National Science Foundation, which supplies about three quarters of the federal support for ground-based astronomy, is cutting back on funding for astronomy. When corrected for inflation, the operating funds provided for astronomy by the NSF have been cut back by one eighth since 1984.

NSF funds the National Optical Astronomy Observatories, which operates observatories in Arizona, Chile, and New Mexico. The funding cuts in NSF's current budget proposal will certainly force one or more major facilities to close in the next year, a move that can only intensify the problem of not enough telescope time.

The present funding squeeze is discouraging for astronomers who have worked so hard to find private and state money to build new telescopes. This fundraising effort, which astronomers have carried on throughout this century, continues today as universities join together to build telescopes that they will share. Ironically, astronomers may now wind up with insufficient funds to operate their new instruments effectively.

The cutback in research funding threatens not only ground-based astronomy but space-based science as well. Past federal support of basic research has provided the talent necessary to achieve recent major U.S. space results. The glorious pictures from the *Einstein* x-ray satellite and the *Infrared Astronomical Satellite* have forever altered our view of the universe, and the breathtaking views of Mars, Jupiter, and Saturn by the *Viking* and *Voyager* spacecraft would not have been possible without the expertise of ground-based astronomers.

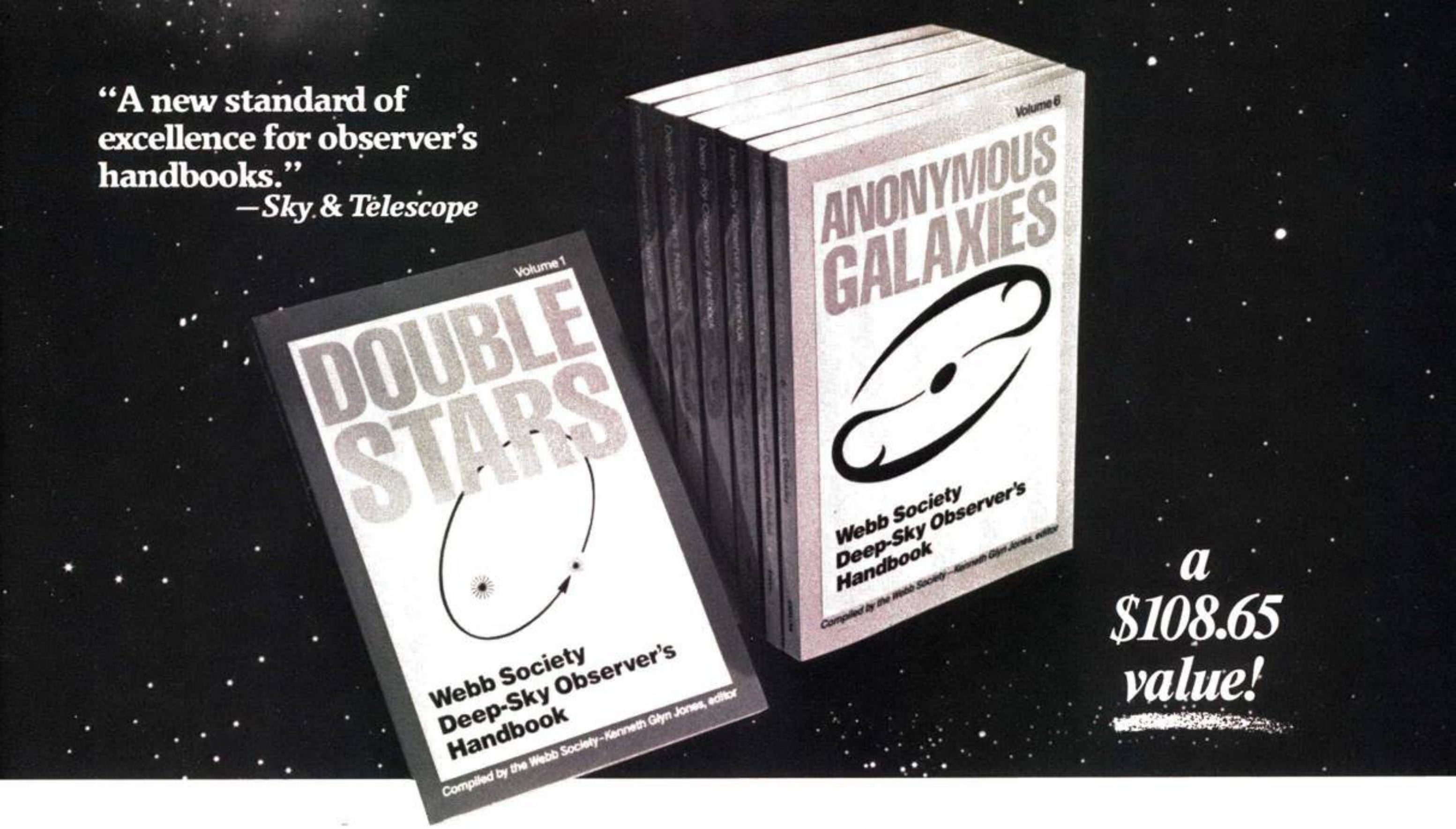
The Wide Field/Planetary Camera on the *Hubble Space Telescope*, for example, was built by Caltech's Jim Westphal, who learned the ins and outs of astronomical instrumentation by developing cameras for several ground-based telescopes.

Astronomers may not have the money to run their new telescopes.

In this era of spectacular space instrumentation a strong program of ground-based astronomy is more important than ever. Now that we have several major space instruments scheduled for launch within the next three years, a strong ground-based program is absolutely vital for successful research. As each new spacecraft uncovers many new objects, observers on Earth need to follow up these discoveries with hours of telescope time to complete our understanding of what the new objects are and how they fit into our picture of the universe.

At the same time that the United States is cutting back its support of astronomical research, other countries are investing more heavily in astronomy. We can already see the negative effects of this imbalance as a few U.S. trained astronomers move to other countries where they see a much brighter future. The assistant director of NOAO for new telescope technology has gone to Europe because he feels the funding situation in the United States is hopeless. Such moves do not auger well for the future of American astronomy.

If this trend of shrinking support for astronomy concerns you, make your voice heard by contacting your congressman. Also write to the Senate Appropriations Committee, U.S. Senate, Washington, DC 20510; the House Appropriations Committee, U.S. House of Representatives, Washington, DC 20515; and Eric Bloch, Director, National Science Foundation, Washington, DC 20550.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ECHOES OF THE SUPERNOVA EXPLOSION

The discovery of a "light echo" from the explosion of supernova 1987A will allow astronomers to map the three-dimensional structure of interstellar clouds in the supernova's neighborhood. The echo — analogous to a sound echo created when sound waves bounce off an object's surface — comes from light emitted early in the supernova's evolution that has been reflected off dust particles in the Large Magellanic Cloud.

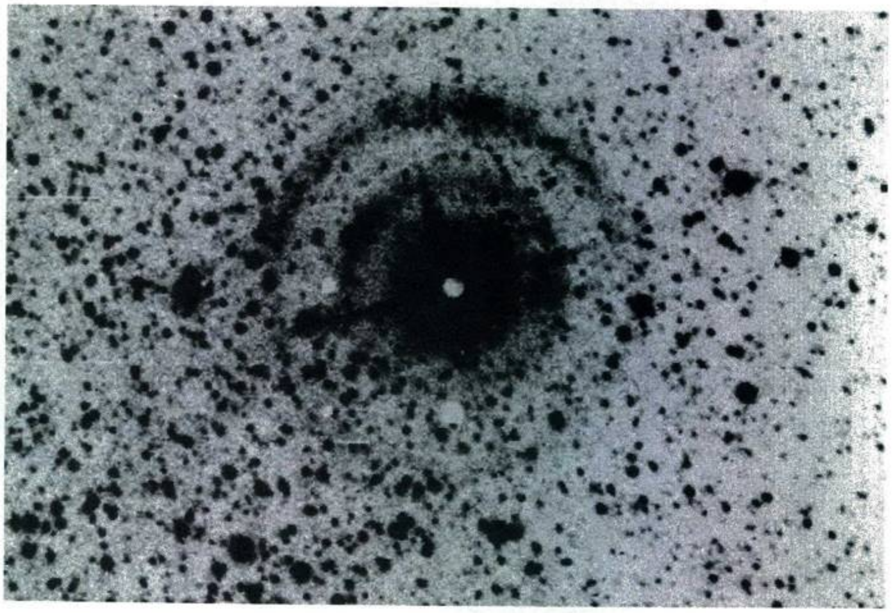
Arlin Crotts of the University of Texas at Austin discovered two faint light echoes with the 40-inch telescope at Las Campanas Observatory in Chile on March 3. He used an instrument called a coronagraph to block light from the supernova, which was then more than 10,000 times brighter than the echoes.

The light echoes appear as arcs: one lies 32 arcseconds from the supernova and the other 47 arcseconds away. From the dimensions of the arcs and the delay between the explosion and the echo's detection, Crotts estimates that the interstellar clouds reflecting the light lie roughly 440 light-years and 900 light-years in front of the supernova's location, respectively.

Future observations will give astronomers a detailed look at the interstellar environment surrounding the supernova — information that is impossible to get any other way. Brad Schaefer of NASA's Goddard Space Flight Center, who predicted the light echo last year, expects the echo to remain visible for decades to come. The echo should grow larger and fainter as time goes on, but it should also become more prominent as the supernova rapidly fades. A decade from now Schaefer expects the echo to be roughly 11th magnitude and 6 arcminutes in diameter. A century from now the echo should be 20 arcminutes in diameter and glow at roughly 13th magnitude.

A light echo is just one of many interesting predictions astronomers have made about the supernova's future. Infrared astronomers Robert Gehrz and Edward Ney of the University of Minnesota predict that dust grains may form in the expanding debris of supernova 1987A within a year or two.

Gehrz and Ney believe dust grains will condense if the expanding gaseous debris has a high enough density when its temperature falls to 700° Celsius. If this happens, the supernova's infrared emission will increase. The dust might also block a significant amount of visible light, which would cause 1987A to dim considerably.



FAINT WISPS OF LIGHT are echoes of the explosion of supernova 1987A — the supernova's light reflected by dust in the Large Magellanic Cloud. The light echoes appear as two concentric rings around the overexposed image of the supernova itself.

Working at the high-energy end of the electromagnetic spectrum, Alice Harding of Goddard Space Flight Center and Thomas Gaisser and Todor Stanev of the University of Delaware predict that extremely high-energy gamma rays may soon reach Earth from the supernova. These gamma rays would confirm that a pulsar lies at the center of the supernova.

Unlike the gamma rays created by radioactive decay that were first seen late last year, these higher-energy gamma rays would be produced by high-speed protons and electrons accelerated by the pulsar. The researchers expect the gamma rays to reach Earth shortly and to continue arriving for five to ten years.

Farther down the road, Kenneth Brecher of Boston University predicts that 1987A will "re-explode" roughly ten years from now. Based on historical supernova records from many different cultures, Brecher believes supernovae can brighten significantly sometime between ten and fifty years after the initial explosion. Among the more dramatic instances of a reappearance were the supernova of 1006, Tycho's supernova of 1572, and Kepler's supernova of 1604.

Brecher believes these reappearances were caused by debris thrown off by the explosion colliding with a shell of material released by the progenitor star thousands of years earlier. The collision excited the gaseous shell and triggered the brightening.

If this scenario holds for 1987A — and there is ample observational evidence that a shell of material exists about 1 light-year from 1987A — then in about ten years 1987A will reappear. Although the reappearance will not be as bright as the original explosion, it may reach 10th magnitude and thus be easily visible in a small telescope.

STARBURST ERA IDENTIFIED IN DISTANT GALAXY

Large numbers of hot, massive stars in the nucleus of the distant, far-infrared galaxy *IRAS* 01003-2238 indicate that a "starburst" era must have occurred in the galaxy's recent past. This finding contradicts the previous assumption that *IRAS* 01003-2238 and other galaxies undergo continuous star formation at a reasonably steady rate.

Astronomers Lee Armus and Timothy M. Heckman of the University of Maryland and George K. Miley of the Space Telescope Science Institute observed *IRAS* 01003-2238 with the 4-meter telescope at Cerro Tololo Interamerican Observatory in Chile. *IRAS* 01003-2238 is a large, energetic galaxy located 600 megaparsecs away in the constellation Cetus. The spec-

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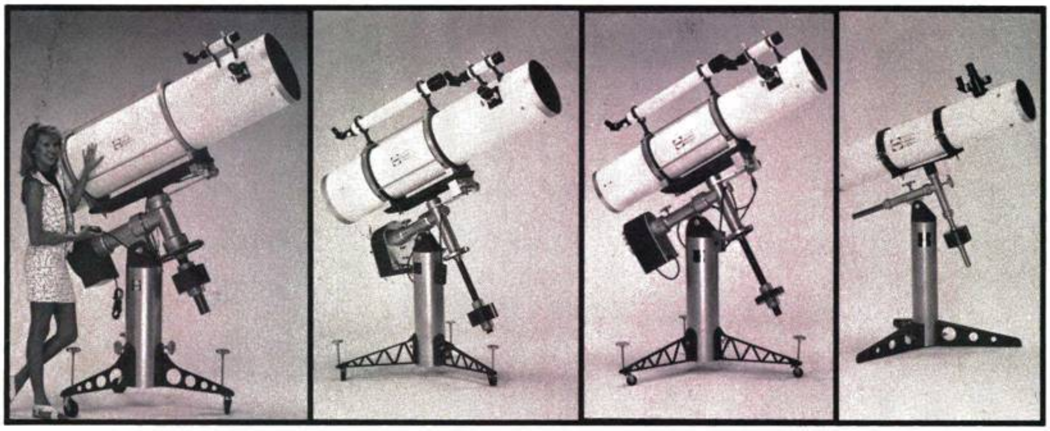

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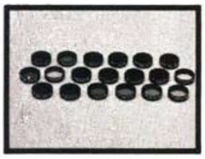

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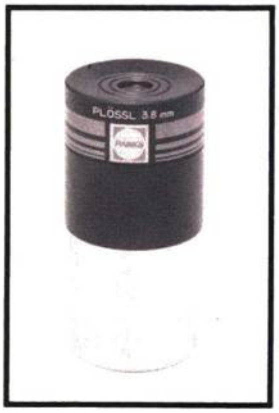

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tra the astronomers recorded show a broad emission band in this galaxy's light at 4660 angstroms that is, according to the astronomers, caused by approximately 130,000 Wolf-Rayet stars. The astronomers arrived at this figure by measuring the intensity of various emission lines thought to be produced by Wolf-Rayet stars. (By comparison, around three hundred Wolf-Rayet stars have been identified in the Milky Way and neighboring galaxies.)

Wolf-Rayet stars are hot, luminous stars poor in hydrogen that continuously lose mass to the surrounding space. They are thought to be hot O stars of 20 to 40 solar masses, stripped of their atmospheres down to energetic cores. The spectral lines observed in *IRAS* 01003-2238 are caused by the expanding bubbles of gas surrounding the 100,000 Wolf-Rayet stars in this galaxy. The huge number of these stars in *IRAS* 01003-2238 indicates that many stars were produced in the galaxy around 10 million years ago because they would have required that much time to evolve into Wolf-Rayet stars.

However, the astronomers also note a conspicuous absence of normal O stars relative to the number of Wolf-Rayet stars. Certainly huge numbers of O stars, which are far more common than Wolf-Rayet stars, would have been produced had star formation occurred in *IRAS* 01003-2238 over the past 10 million years.

This study offers two significant results toward understanding powerful far-infrared galaxies like *IRAS* 01003-2238. First, the detection of Wolf-Rayet stars in this galaxy is the best evidence to date for the existence of hot, massive, young stars in these galaxies. Second, the ratio of Wolf-Rayet to O stars indicates that star formation in the galaxy has declined sharply over the past 10 million years.

Together these conclusions point to a starburst epoch in the galaxy's past and demonstrate that galaxies like *IRAS* 01003-2238 do not undergo continuous star formation. This suggests that other galaxies may produce stars in bursts rather than at steady rates. If pursued by other astronomers for other galaxies, this idea may significantly change the way astronomers look at the behavior and evolution of galaxies.

NEW TECHNOLOGY TELESCOPE NEARS COMPLETION

MORE SOPHISTICATED than any other telescope in the world, ESO's New Technology Telescope will be in operation by this year.

The European Southern Observatory's advanced New Technology Telescope (NTT) will be in operation by the end of 1988. In February the unusual octagonal "dome" to house the 3.5-meter NTT arrived in Chile for installation at the La Silla observatory. When the NTT is installed later this year, it will be the most advanced telescope in the world.

The observatory is designed to be as open to outside air as possible, and the floor of the building and the telescope and instrument rooms are cooled to the outside air temperature. As a result there will be less heating of the air around the NTT and images of astronomical objects will be sharper.

Although the primary mirror is 3.58 meters (141 inches) in diameter, it is only 24 centimeters (9-1/2 inches) thick. Because so thin a mirror is quite flexible, it must be held by computer-activated supports. This technique will ensure that the NTT will give the best possible image quality in every position.

The ultraprecise altazimuth mounting for the NTT will point the telescope with an accuracy of 1 arcsecond, a figure unsurpassed by any other large telescope.

ESO decided to build the NTT in 1982 to test the most advanced technologies in optics, mechanics, and computer science. The goal was to apply Europe's technological prowess to the construction of the world's best telescope in the 4-meter class but at only a third of the usual cost.

Space News

HIGH MARKS FOR SOVIET MARS MISSION

The first spacecraft in thirteen years to head toward Mars will be launched this July by the Soviet Union. According to U.S. scientists, the *Phobos* mission, a pair of probes that will investigate Mars and its two moons Phobos and Deimos, is an ambitious and daring endeavor that clearly demonstrates recent Soviet advances in space science.

"Soviet space technology in general has not been up to U.S. capabilities," said Larry Esposito, associate professor at the University of Colorado (Boulder) Laboratory for Atmospheric and Space Physics. "A decade ago we had a clear lead in every aspect of space science technology, but the gap has been getting smaller. There is some argument now as to whether it exists at all."

The sheer scale of *Phobos* — thirty-one instruments from twelve countries studying the Martian system, the Sun, and the solar wind — puts it in the big leagues. "*Phobos* is a very solid mission," said Esposito, who is working on both the Soviet mission and the U.S. *Mars Observer* mission scheduled for launch in 1992. "It is a larger-scale mission than *Mars Observer*, which has much more focused objectives and only a half-dozen instruments." (For profiles of both missions, see ASTRONOMY, November 1987.)

The Soviets' powerful launch capability is one reason such a diverse mission can be undertaken, according to James Head, professor of geological sciences at Brown University and an interdisciplinary scientist on *Phobos*. "The sheer weight requirements of getting something like their laser probe into orbit probably would have precluded us from doing it," said Head. "Their big payloads give them a lot of latitude to try different things. They don't automatically have to rule out things that aren't the highest priorities or are not totally proven."

Taking risks and trying new technologies is a dominant trait of *Phobos*. "At the time the Soviets were considering new missions to Mars, they saw several new technologies developing — directed energy beams and lasers — that the United States hadn't used before," said Esposito.

"As far as the scientific use of lasers is concerned, the *Phobos* laser is pushing the state of the art," said Esposito. "The application of moving particle beams and lasers to stir up the surface of an object and measure the components with a mass

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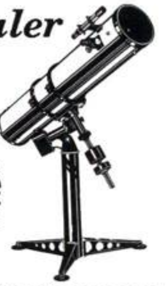

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Here's a superb *56% savings* on a superb 8" telescope – the state-of-the-art Meade 2080/LX5. You get all these features and accessories: the latest multi-coated optics group; 9 x 60mm illuminated polar axis finder; 2" mirror star diagonal with 1.25" adapter; 1.25" Series 4000 Super Plossl eyepiece; quartz-controlled electronic drive with power adapters for AC, DC, and penlight battery operation; hand control with built-in map light, controls for optional electric focuser, drive corrector, and 8x image scanning; equatorial wedge; adjustable height tripod; foam-lined carrying case with lock; lifetime warranty, and more! *$3600 list,* **for only $1595!** (The optional $\$160^{00}$ #39 dec motor that converts the LX5 drive into a dual axis drive corrector for astrophotography is only $\$99^{50}$.) Less than 70 available in stock and on order at this special sale price, so don't miss out on this super opportunity!

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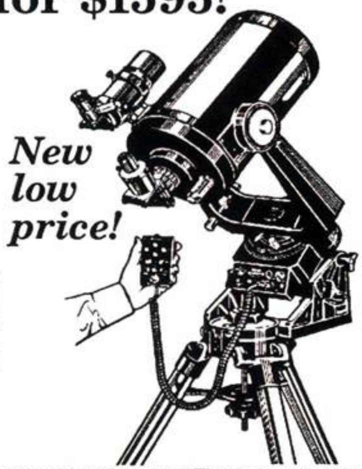

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The latest Celestron C90 spotting scopes, from $379!

Celestron has updated their best-selling C90 spotting scopes – and we've got them all in stock! These are not the discontinued, inverted finder image, uncoated models that some dealers offer. These are the very latest models – some with *multi-coated* optics for visibly higher light transmission and increased contrast, some with rubber armor for hard use in the field. Each has an 8x finder with a very wide 7° field and upright/correctly-oriented images, plus a 45° prism diagonal that provides both upright and correctly oriented images *and* a comfortable viewing angle. Each comes with a 33x eyepiece and a unique Samsonite-type carrying case that is fitted to hold your camera and photo accessories, as well as the spotting scope! They're super 3.5" f/11 spotting Maksutov scopes at sensible prices that save you over 40%!

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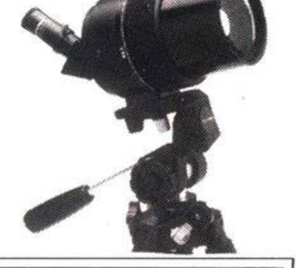

Last chance on filter/eyepiece closeouts!

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spectrometer — that's a new thing that has not been done in space. It's a very powerful technique that improves on reflectance spectroscopy, which gives a general idea of what minerals are present but not in what quantities. It's not as good as testing samples in a laboratory, but for the money it is a very effective technique."

To use the laser sensing, the spacecraft will try another new technique: flying at a very low altitude as it orbits Phobos. "This is incredibly imaginative," said Head. "If you had approached our engineering community to do such a thing, the initial reaction would have been one of horror, because it appears to be very risky. The fact that Soviet scientists and engineers have been able to come together with a plan like this — a very ambitious engineering feat — is quite remarkable. It shows that they are really in an exploration phase, that they're going to try things that have a high payoff but at the same time a high risk."

International involvement in *Phobos* is another factor contributing to the scope of the mission. "It allows the Soviets to do more, to defer much of the cost, and expand the mission's scientific and technical capabilities," said Head, who has been working with Soviet scientists for the past fifteen years.

"International cooperation is really a hallmark of the Soviet space program," he said. "The *Vega* mission to Comet Halley had almost as much international involvement as *Phobos*. I think that for the Soviets space is much more a part of foreign policy than it is in our country."

Involvement of other countries is not, according to Head, an indication of a lack of Soviet capability. "If you think the Soviets can't do these things on their own, look at the Soviet-built *Venera* landers they put down on Venus. They gathered a lot of information under extreme conditions. We have not done that."

Phobos will return a wealth of information including data that should allow scientists to conclusively determine whether or not Phobos is a captured asteroid. The data that the *Phobos* orbiter will return on the Martian surface at mid-latitudes will be used in planning the next stage of Soviet Mars exploration scheduled for 1994.

EIGHTH ANNUAL SPACEWEEK EVENTS HELD JULY 16-24

In this election year the goal of Spaceweek '88, a weeklong, nationwide commemoration of the first Moon landing, is convincing the American public that the United States needs a strong space program. The hope is that strong public support will in turn convince the presidential candidates to commit the country to an aggressive, successful space program.

The theme of this year's Spaceweek celebration, held annually on July 16-24, is "Space: A Commitment to Our Future." Grassroots efforts — lectures, conferences, educational displays, space camps — will be aimed at showing the public how the technological spinoffs of the space program have had a significant impact on America's economy, culture, and quality of life.

Last year more than 79,000 people attended Spaceweek events in seventy cities, sponsored by astronomy clubs, planetariums, and museums. Spaceweek, Inc., chartered by the State of Texas, oversees a national program of celebrations that focus public attention on space exploration.

For information on Spaceweek activities in your area, write Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77258, or contact local astronomy and space organizations.

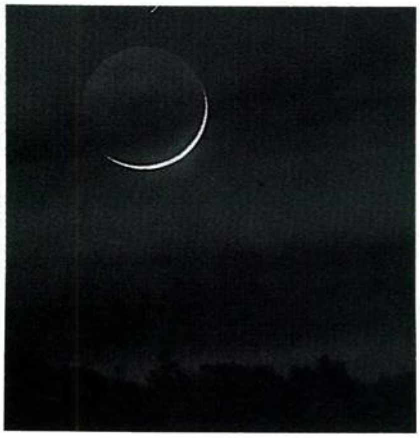
Amateur News

TRY SOME BACKYARD SCIENCE

Three special observing projects are being conducted this summer that let every observer — even observers without telescopes — contribute to the science of astronomy.

For naked-eye observers, the U.S. Naval Observatory needs help spotting the crescent Moon on July 14. Observers with 6-inch and larger reflectors can try to glimpse the elusive "ashen light" on Venus as part of a worldwide program conducted by the Association of Lunar and Planetary Observers. And this year's big astronomical event — the opposition of Mars — will be the focus of summer-long scrutiny.

You might not think there was anything left for astronomers to learn about the Moon from naked-eye observations, but there is. Although astronomers can accurately determine the position of the Moon in the sky, they cannot yet predict the exact time or location on Earth where the young crescent Moon can first be seen. This is a critical timekeeping event for Eastern cultures that end a month when the crescent Moon is first visible.



FIND THE CRESCENT MOON on July 14 for U.S. Naval Observatory astronomers.

The Naval Observatory's current calculations for July place first visibility somewhere in North America or the Caribbean. But to get a better fix than that, the Observatory is organizing a continentwide network of observers for July 14.

Anyone with a clear western horizon and an hour to spare immediately after sunset can help. Because the Moon will be very low above the horizon (2°-5° elevation), an unobstructed horizon is essential. A brief reporting form is available by writing to "Looking for the Moon," U.S. Naval Observatory, Washington, DC 20392.

A much more elusive — and controversial — phenomenon is the target of ALPO's ashen light observing program. For the past three hundred years astronomers studying Venus in its crescent phase have reported faint glows on the planet's dark hemisphere around the time Venus lies between the Earth and Sun. The cause of the light is not known.

Scientists working on the *Pioneer Venus Orbiter* spacecraft, which has been studying the planet since 1978, are trying to find the cause by coordinating spacecraft observations with Earth-based observations.

Pioneer Venus staff member Christopher T. Russell of the University of California at Los Angeles is working with Julius Benton, Jr., of ALPO's Venus Section to get planetary observers to moni-

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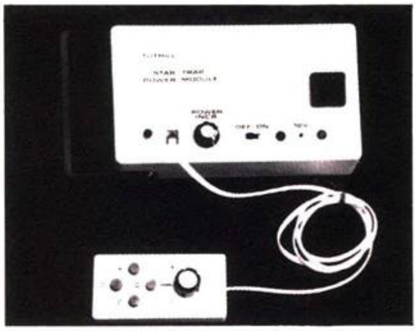

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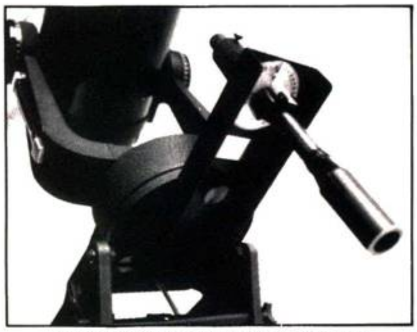

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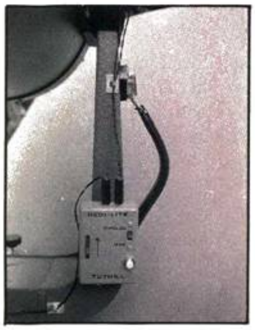

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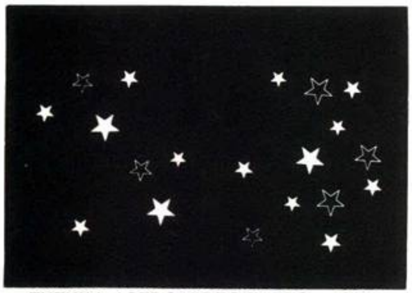

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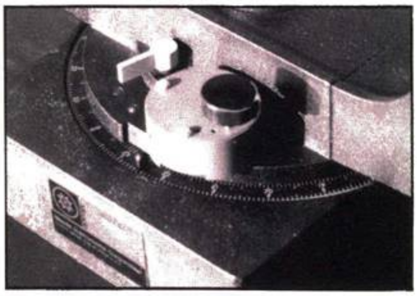

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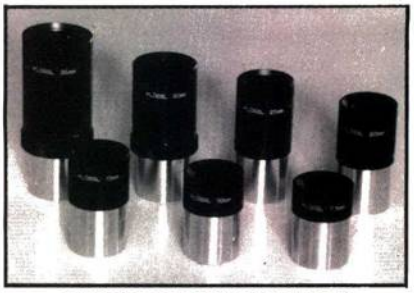

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tor Venus through 1989 when the orbiter will cease functioning.

According to Benton, this is a good project for observers who want to try out regular planetary observing. With modest equipment — a 3-inch refractor or 6-inch reflector, filters, and an occulting bar to block the bright glare of the sunlit side of Venus — an observer can begin. ALPO provides observing handbooks as well as individual coaching for new observers. For more information, write to Julius Benton, Jr., ALPO Venus Section, Associates in Astronomy, 305 Surrey Road, Savannah, GA 31410.

For observers who want to seriously study Mars this year, ALPO and the Planetary Society have published the "Mars Observer's Handbook." This booklet contains everything you need to know to observe the Red Planet: an introduction to Mars and its seasons, how to draw the Martian disk, and how to record and report your observations to ALPO.

The handbook comes with a supplement on the 1988 Martian apparition written by Fred Espenak and Michael Mumma of NASA's Goddard Space Flight Center. Both are available for $5, plus $1 for handling, by writing to the Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106.

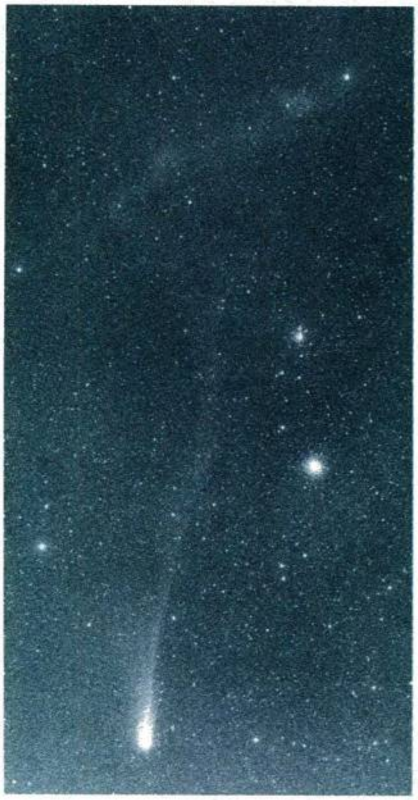
DID ANYONE PHOTOGRAPH THIS COMET?

Comet Bradfield did something unexpected last fall and a NASA astronomer would like some help from astrophotographers in determining just what happened.

Last October astronomer Dan Klinglesmith and coworkers Elliott Moore and Philip Bernick photographed the comet from NASA's Joint Observatory for Cometary Research near Socorro, New Mexico. Four photos taken on the night of October 19 with the observatory's 14-inch Schmidt camera show a remarkable kink shaped like a backwards "?" in the comet's ion tail. This feature is absent in photos taken the nights before and after.

Klinglesmith is hoping that backyard astrophotographers can help fill the gaps in the photo record. To see how the kink in the tail developed and decayed, as well as view these changes in context, Klinglesmith would like to see any photographs of Comet Bradfield taken from October 16 to 22, 1987.

Knots and twists in a comet's tail are a well-known phenomenon. They occur as the comet's electrically charged ion tail responds to shifting magnetic fields in the solar wind — much the way a yacht pennant flaps wildly on a gusty day.



AN ENIGMATIC KINK in the tail of Comet Bradfield leads a NASA astronomer to ask for help from backyard astrophotographers.

More rarely, conditions are such that the interplanetary magnetic field actually pinches off a section of a comet's ion tail. Disconnected from the comet head, the fragment drifts downstream on the solar wind at about 200 to 400 kilometers per second. Meanwhile, a new ion tail begins to form immediately at the comet's head and swiftly grows to replace the disconnected section.

While Bradfield's "wiggle" is not unique — similar ones were seen in Comet Moorhouse (1908 III) and Comet Tomita-Gerber-Honda (1964c) — what sets this event apart is its enormous extent. Klinglesmith calculates that the kink is more than 10 million kilometers long — apparently the largest ever seen.

Explaining the feature is difficult. While its downstream velocity lies in the right range for a disconnection event, the feature appeared with exceptional rapidity. A small disturbance was visible in the tail near the nucleus in the previous night's photos, but its outward velocity was high enough to have carried it far beyond the location of the kink by the next day.

If you have slides or prints of the comet taken between October 16 and 22, 1987, and wish to contribute them, mark each with full data — name and address, telescope or equipment used, film emulsion, and exposure date, time, and duration. Carefully package the photos to prevent bending and send them insured. (If you want them returned, include a stamped, self-addressed return envelope.) Send them to Daniel Klinglesmith, Mail Code 684, Goddard Space Flight Center, Greenbelt, MD 20771.

WARM NIGHTS, WINTER SKIES AT FLORIDA STAR PARTY

Remember winter? All those nights ruined for observers by arctic temperatures, storm clouds, and biting winds. For a lot of people, amateur astronomy completely shuts down for four or five months each year. But three hundred observers escaped winter's hold last February — and found dark skies plus a view of the southern sky — at the Winter Star Party in southern Florida.

Sponsored by the Southern Cross Astronomical Society of Miami, the fourth annual event — the only large U.S. star party during the winter months — was held February 18-21 at Big Pine Key on the southern tip of Florida. The location is the southernmost dark sky site in the continental United States (25.4° latitude) and has an unobstructed panoramic view of the southern sky.

This year's event, which had previously been held in the Florida Everglades, had two nights of clear skies, over 150 telescopes in sizes up to 20 inches on the observing field, and, according to organizer Tippy D'Auria, a surprising number of refracting telescopes. "Refractors were there en masse," said D'Auria. "I think we're seeing a comeback of refractors as a portable instrument."

A favorite target for observers, who came from as far away as Alaska and New England, was Omega Centauri. "We went right into the heart of the thing, looking at the dark spots in the center and seeing more and more stars as we increased the magnification," said D'Auria. "It was like *Star Trek* — going where no man had gone before."

During daylight hours a program of lectures on collimation, astrophotography, telescope design, and meteorites competed with swimming and scuba diving for observers' attention.

Next year's Winter Star Party is tentatively scheduled for February 2-5. There is a $15 registration fee and a $7 fee for additional family members. Watch ASTRONOMY's Meetings and Events calendar for details.

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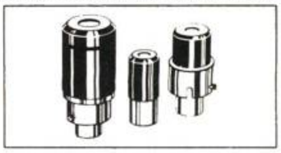

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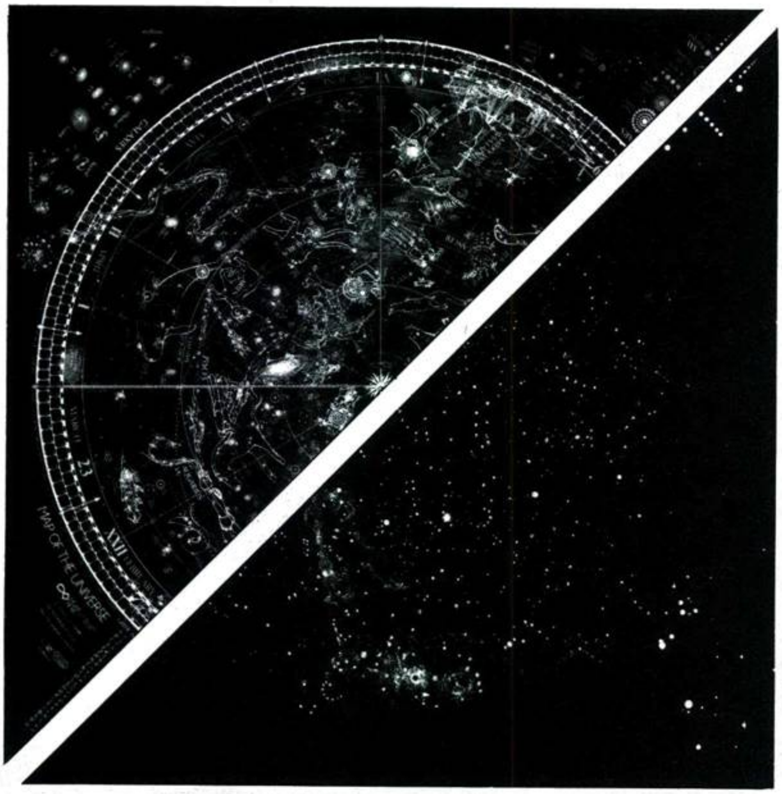

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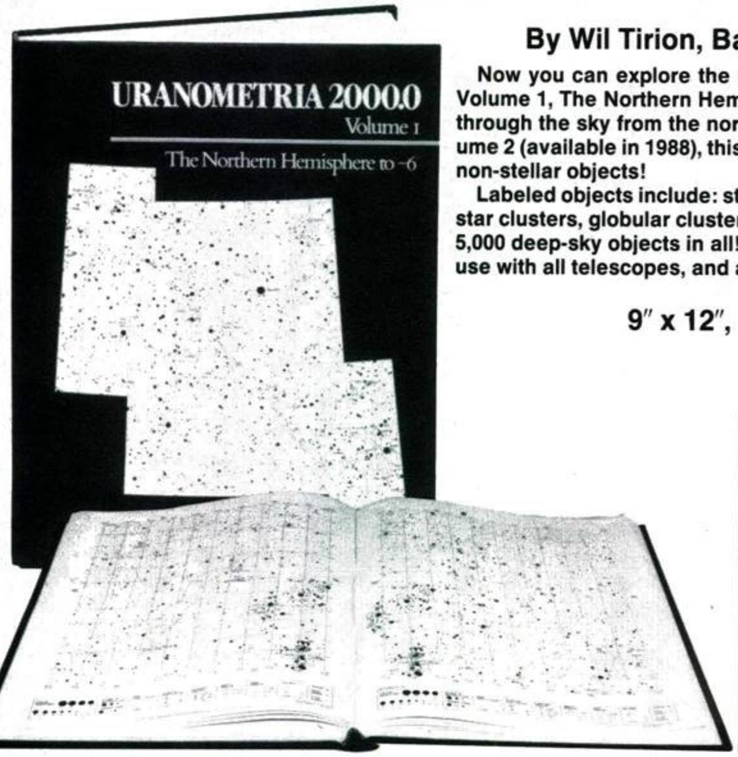

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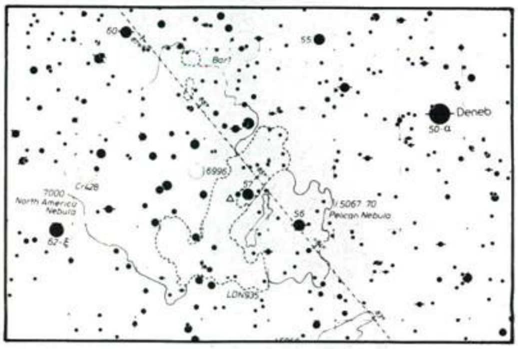

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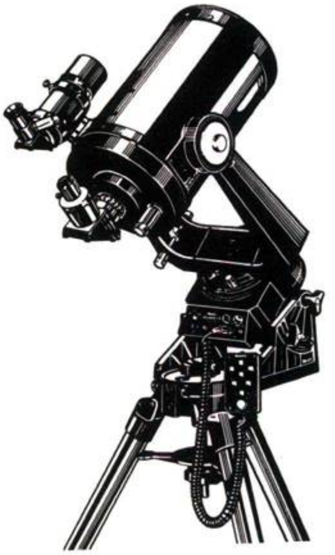

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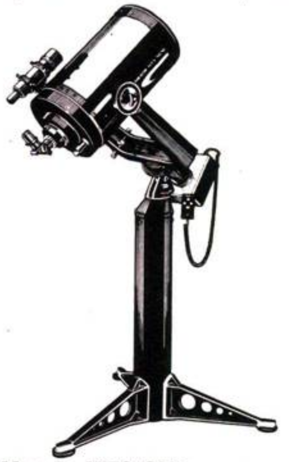

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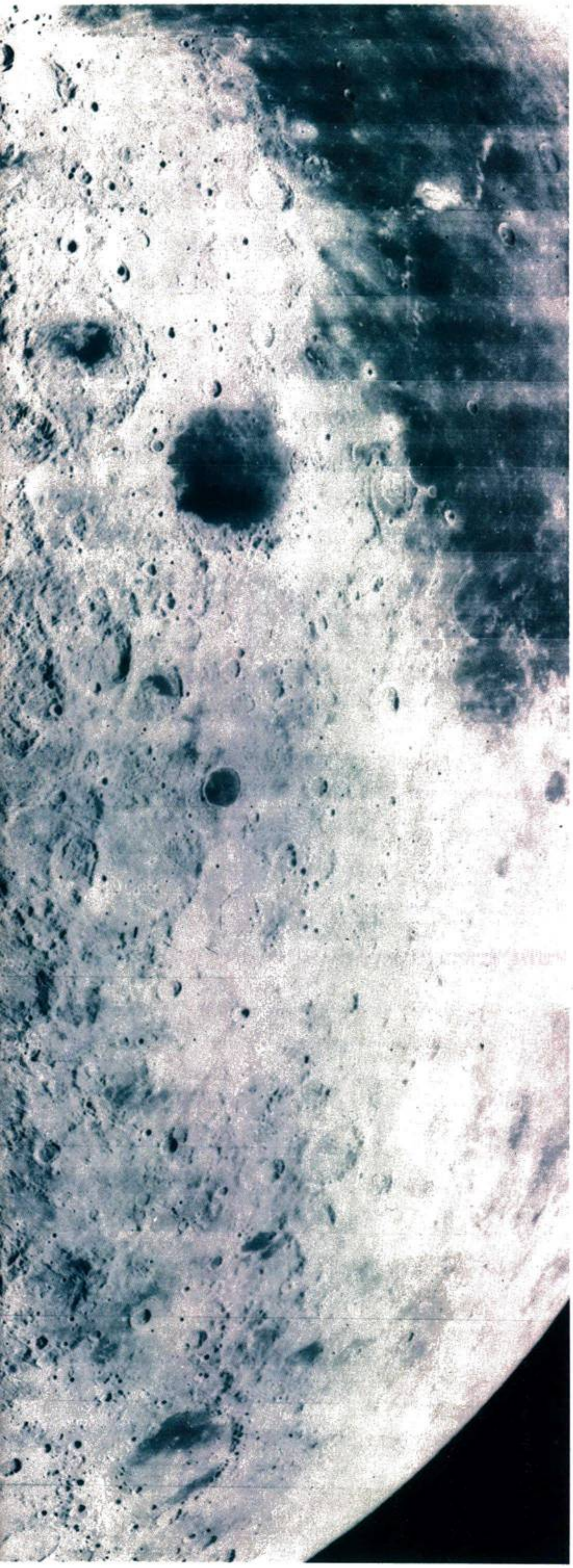
The Chronology of Planetary Bombardments

From the origin of the Moon to the extinction of the dinosaurs, collisions have had a major impact on the solar system.

by Patricia Barnes-Svarney



Chaos and order, the predictable and the accidental — each has had a role in the formation of our solar system. While planets and their satellites were systematically evolving over the last 4.5 billion years, one-of-a-kind events — like the collision of one satellite with another — broke this measured evolution to rearrange entire worlds and set them on different paths.

Long relegated to the sidelines of planetary science, collisions and impacts are now acknowledged as major factors in the history of the solar system. The influence of such collisions goes far beyond the surface scars of impact craters visible on the inner planets and many of the outer planets' satellites. The formation of planetary atmospheres, the creation of our Moon, and the periodic extinctions of entire species of life on Earth are just a few chapters in the history of the solar system that may have been caused by collisions.

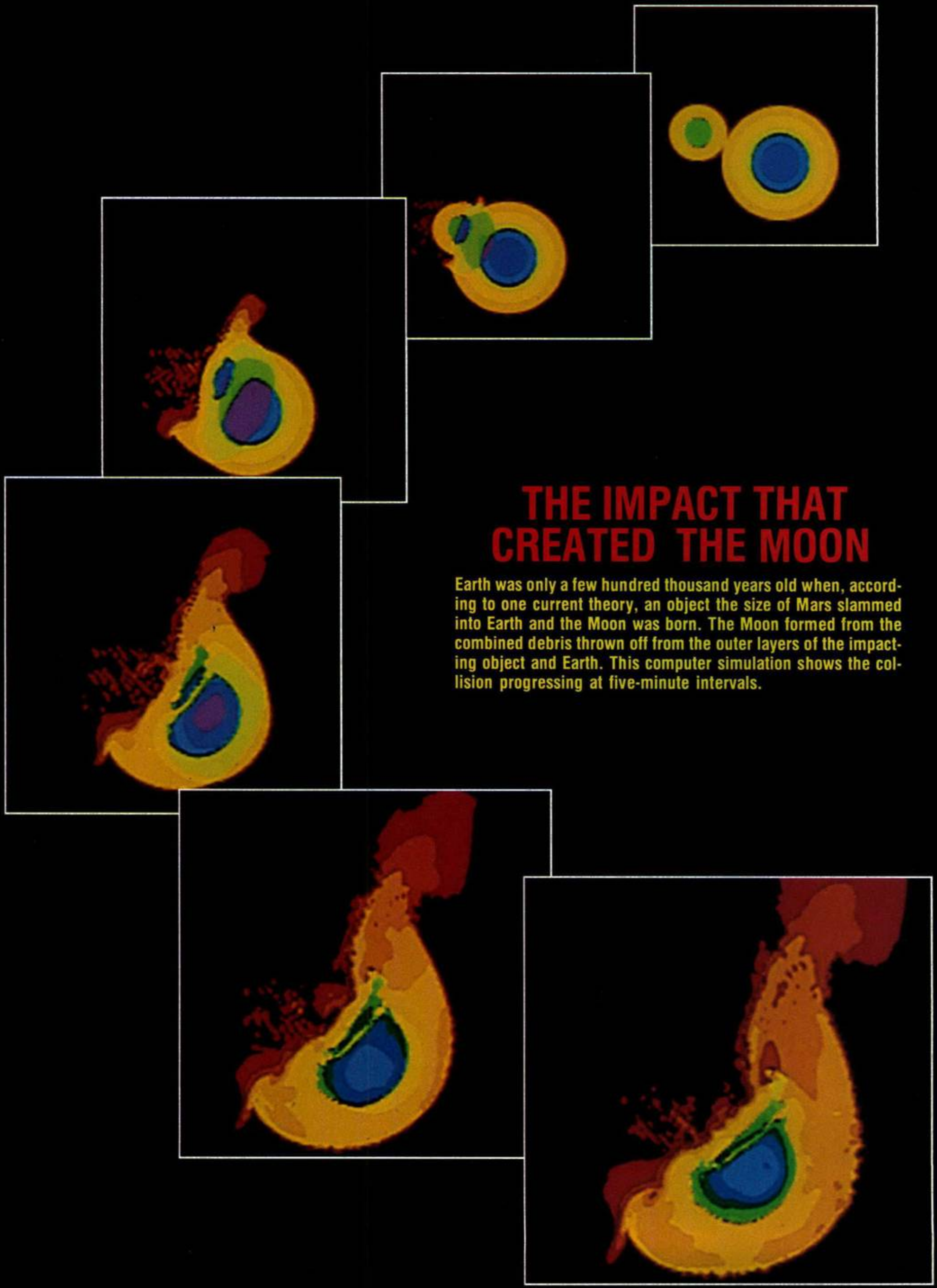
The collisional evolution of the solar system is the story of planets, asteroids, and comets. Although these objects share a common origin, each has a different history that can be understood only when we understand the history of all three.

Theory states that our solar system began just over 4.6 billion years ago when a huge cloud of dust and gas began to collapse into a spinning, circular disk. At the hub of this vast wheel was a knot of material, the proto-Sun. Gravity pulled material toward the center of the cloud and the resulting friction warmed the nebula.

As the nebula condensed, pockets of matter formed grains that began to adhere to one another. Hundreds of bodies called planetesimals grew. The planetesimals in the inner solar system condensed into bodies of silicates and iron because they were close to the Sun, while in the colder outer solar system, ammonia, water, and methane condensed as solids. These solids accumulated with dust to form the giant planets.

The planetesimals in the inner solar system ranged from Mars- and Moon-sized pieces to much smaller

LIKE A BULL'S EYE on the Moon, the concentric rings of the Orientale Basin were formed by the impact of a 100-mile-wide object. If that object had hit central Ohio, the basin would stretch from Chicago to Washington, D.C.



THE IMPACT THAT CREATED THE MOON

Earth was only a few hundred thousand years old when, according to one current theory, an object the size of Mars slammed into Earth and the Moon was born. The Moon formed from the combined debris thrown off from the outer layers of the impacting object and Earth. This computer simulation shows the collision progressing at five-minute intervals.

debris. It has been estimated that several bodies the size of Mars, ten bodies larger than Mercury, and a hundred objects the size of our Moon orbited in the region of the terrestrial planets along with countless fragments of smaller debris. The large pieces eventually collided to form Mercury, Venus, Earth, and Mars.

As the planets grew, they swept up much of the remaining debris, which added to the total mass of the planets. Other chunks of planet-forming materials continued to wander the solar system. Some remained orbiting in the plane of the original nebula along with the planets; others, because of collisions or gravitational nudges from larger planetesimals, were thrown out of the ecliptic plane into eccentric orbits.

The 4.5 billion-year-old history of solar system collisions has been played out in the complex interactions between comets, asteroids, and planets.

Between 4 billion and 3.8 billion years ago — after the surfaces of the terrestrial planets had solidified — the remaining planetesimals in the inner solar system appear to have been responsible for a major intense bombardment of the planets. The outer solar system also experienced a period of major bombardment, but it is not known whether that bombardment occurred at the same time as the bombardment in the inner solar system. Collectively this era is called the Late Heavy Bombardment.

On the Moon the scars of this bombardment are dramatic and clear. Objects up to 100 miles across crashed into the Moon and formed at least eight huge, ringed basins more than 150 miles across. The Orientale Basin, which stretches over 500 miles wide, was created in this period by an object approximately 100 miles across.

Dynamic Leftovers: Asteroids and Comets

In one region of the solar system — between the orbits of Mars and Jupiter — the planetesimals did not evolve into a planet even though there should have been enough material in this area to form one. The tremendous gravitational influence of Jupiter on this area, the asteroid belt, caused the planetesimals to violently collide rather than coalesce into a planet.

The history of the asteroid belt continued to be chaotic. Large asteroids collided with other asteroids, which slowly ground the material in the belt into smaller and smaller pieces and threw some fragments out of the belt altogether. The planets, especially Mars and Jupiter, then perturbed the asteroids into various eccentric orbits, which often sent asteroids into the path of the planets.

The mass of the asteroid belt today — equal to about 2 percent the mass of the Moon — is much smaller than the original mass of the region. The asteroid belt has been depleted by collisions that have left distinct clusters of asteroids called Hirayama families, which travel in roughly the same orbit. Another mechanism that might have depleted the asteroid belt was large planetesimals, scattered into the region by Jupiter, that gravitationally perturbed asteroids into planet-crossing or escape-bound trajectories.

The objects in the asteroid belt have been so pushed and pulled around that it is not known whether the material there today originally formed in the belt or was moved there from elsewhere. Some asteroids, especially those with eccentric orbits, may in fact be dead comets, their ice and gas shells stripped away after too many trips around the Sun.

The system of comets has an even more chaotic origin than asteroids. As the planets of the early solar system accreted from the solar nebula, icy planetesimals from beyond the outer solar system were attracted by Saturn and Jupiter. Other icy bodies were thrown out of the solar system and collected in an area beyond the outer solar system called the Oort cloud. Because comets are relatively unaltered bodies formed in the same process that created the outer planets, understanding comets will yield insights into how the outer solar system planets originated.

A halo of icy planetesimals that rings the solar system, the outer reaches of the Oort cloud stretches nearly halfway to Alpha Centauri, the star system nearest the Sun. Long-period comets orbit out to the far edge of the cloud, while short-period comets have orbits much closer to the solar system.

Planets, asteroids, and comets have an intricate history over 4 billion years old. A lot can happen in that amount of time. By examining the planets and moons we see today, scientists are trying to piece together the distant, unseen events that shaped the solar system.

Impact Origin of the Moon

The planetesimals floating around in the early solar system might have formed more than the nine planets — they might have created our Moon. An impact-origin theory of the Moon developed by H. Jay Melosh at the University of Arizona's Lunar and Planetary Laboratory proposes that the Moon was born 3.8 billion years ago when one of the Mars-sized planetesimals struck the early Earth at a low velocity.

The impacting object was in an orbit similar to that of Earth. A computer model of the process shows an impact and a resulting plume of gas "thrown out" in less than thirty minutes. The collision created a disk of molten and gaseous debris in orbit around the proto-Earth. According to recent computer models of the collision, much of the debris cloud formed a slowly rotating bar of material after the impact. The iron from the impactor was in the half of the bar nearest Earth and the lighter rock was in the outer half. The iron particles streamed back into the Earth, penetrating through the mantle to the core. The Moon formed primarily from debris from the impacting body.

There may be evidence of such an impact. "The projectile that struck the Earth was vaporized or melted, but it may have left a chemical scar within the mantle," explained Melosh. "The abundance of 'iron-loving' or siderophile elements, such as gold and platinum, should be 100 to 1 million times less abundant in the Earth's mantle." Early in Earth's history the siderophiles should have migrated to the Earth's iron core. But Earth's mantle is rich in siderophiles, while the Moon lacks these elements. "Therefore," concluded Melosh, "the Moon may be the signature of the pre-impact mantles of the Earth and the impacting body."

Also during the planet-forming stage, planetary atmospheres could have been created in part by impacts. All the inner planets, including Mercury, probably had much larger atmospheres at one time than they do now. But the early Sun's solar wind stripped away many of the gases from the inner solar system bodies. The outer planets, however, were protected by their extreme distance from the Sun and retained their original gaseous envelopes.

As the planets and satellites accreted, larger impacts that occurred on the inner solar system planets may have contributed to the formation of early atmospheres. The Earth's interior, for example, was filled with hot rock and gases. A strike by a planetesimal or meteorite could easily rupture the young crust and release gases such as carbon monoxide, carbon dioxide, nitrogen, and water vapor.

The solar system endured intense bombardment during its first billion years. Massive objects hit the Moon, creating basins hundreds of miles wide.

Icy planetesimals from beyond the orbit of Uranus may have been flung into the inner solar system by Jupiter. These icy bodies would have struck the inner planets, melting or vaporizing on impact and contributing water and other volatile compounds to the planet's atmosphere and surface.

Counting Craters on the Moon

Once the surfaces of the planets and their satellites had solidified, these surfaces began to keep a record of what hit them. And that record of cratering provides clues to the times and natures of the impacts. The early history of inner solar system bombardment has been interpreted largely through the study of the Moon. Because there has been no degradation by atmospheric or geologic action since the Moon's early history, the Moon's craters have remained relatively intact. The Moon is a huge fossil with a comprehensive chronological record of inner solar system bombardment.

Early methods of reading the Moon's crater record were developed twenty-five years ago by Eugene Shoemaker of the U.S. Geological Survey and others. Crater counts in a given area and the relative sizes of the craters were used to determine the relative ages of various landforms on the Moon. Basically, if there are more craters in one area than in another, the first area must be older. The reasoning is that the longer a surface has been exposed, the more impacts it will show.

But the process of crater counting is not as easy as it sounds. Craters can be destroyed or degraded by activity internal to the planet, such as lava flows or crustal movements, and by external activity, such as material or ejecta thrown out by the formation of newer craters. Both processes can modify the evidence of the initial crater populations.

In spite of this difficulty, scientists quickly determined that the Moon's surface could be divided into two epochs: the young, dark maria of ancient lava fields, with few craters; and the older, light-colored highlands, with crater upon crater.

"The dark areas of the maria were shown to have one twentieth as many craters of any given size as in the highlands," said Clark Chapman of the Planetary Science Institute in Tucson, Arizona, "though that doesn't mean that the maria are one twentieth the age of the older highlands, because the flux of impactors has not been constant. We know this to be true on the Moon since we have brought back rocks and dated them."

After lunar samples were returned to Earth by *Apollo* astronauts, absolute ages for the lunar surface could be determined. Samples from the youngest parts of the Moon, the maria, were 3.5 billion years old and the ages of the older craters were around 4 billion years. The differences in age, size, and density of the craters on the Moon showed that the impacts — from the larger basins of the maria to the crater-riddled highlands — were formed by different types of space bodies. In a little more than a billion years the Moon apparently went from a major rain of objects — the Late Heavy Bombardment — to only a very few impacts.

The Early Era of Bombardment

Scientists studying the crater record on bodies throughout the solar system are trying to discern what objects caused the Late Heavy Bombardment. Was it a rain of comets or the gradual cleaning up of planetary debris? Were the bombardments solar system-wide or unique in different regions?

Reading the Moon's fossil cratering record has led to studies of cratering on other planets and satellites. In the inner solar system, scientists assume that the terrestrial planets were affected by much the same population of objects, based on the crater statistics on Mercury, the Moon, and Mars. But scientists studying the outer solar system are not as fortunate as those reading the Moon, because no absolute ages exist for planets and satellites in the outer solar system.

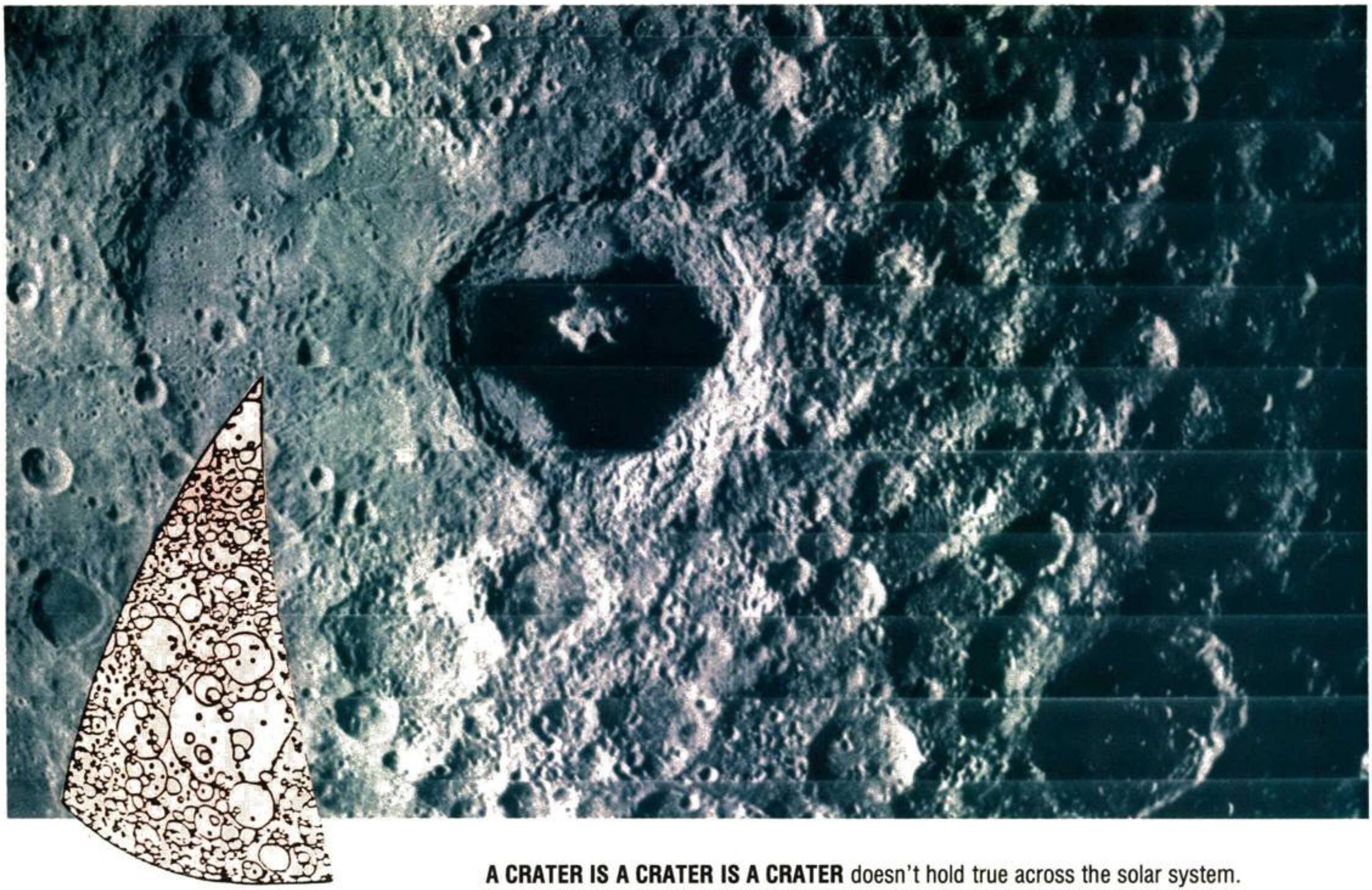
"People have recognized on virtually all of the members of the solar system," explained Melosh, "that there is an ancient era of heavy bombardment. Many assume that this era occurred at the same time on all the planets. We don't know that. The only age we have is for Late Heavy Bombardment on the Moon. There is clear evidence of Late Heavy Bombardment on Mars and Mercury, and it is assumed to be the same period as on the Moon. But until we get samples back from the other planets and satellites we will not know for sure."

Although early conditions in the outer solar system are not known, it is thought that this region had its own group of planetesimals that crashed into the outer planets' satellites. What objects caused impact cratering in the outer solar system continues to be a hotly debated issue. "When you plot the crater statistics, they don't look the same on different bodies in the solar system," said Chapman. "And when you start asking why, that's when you run into disagreements."

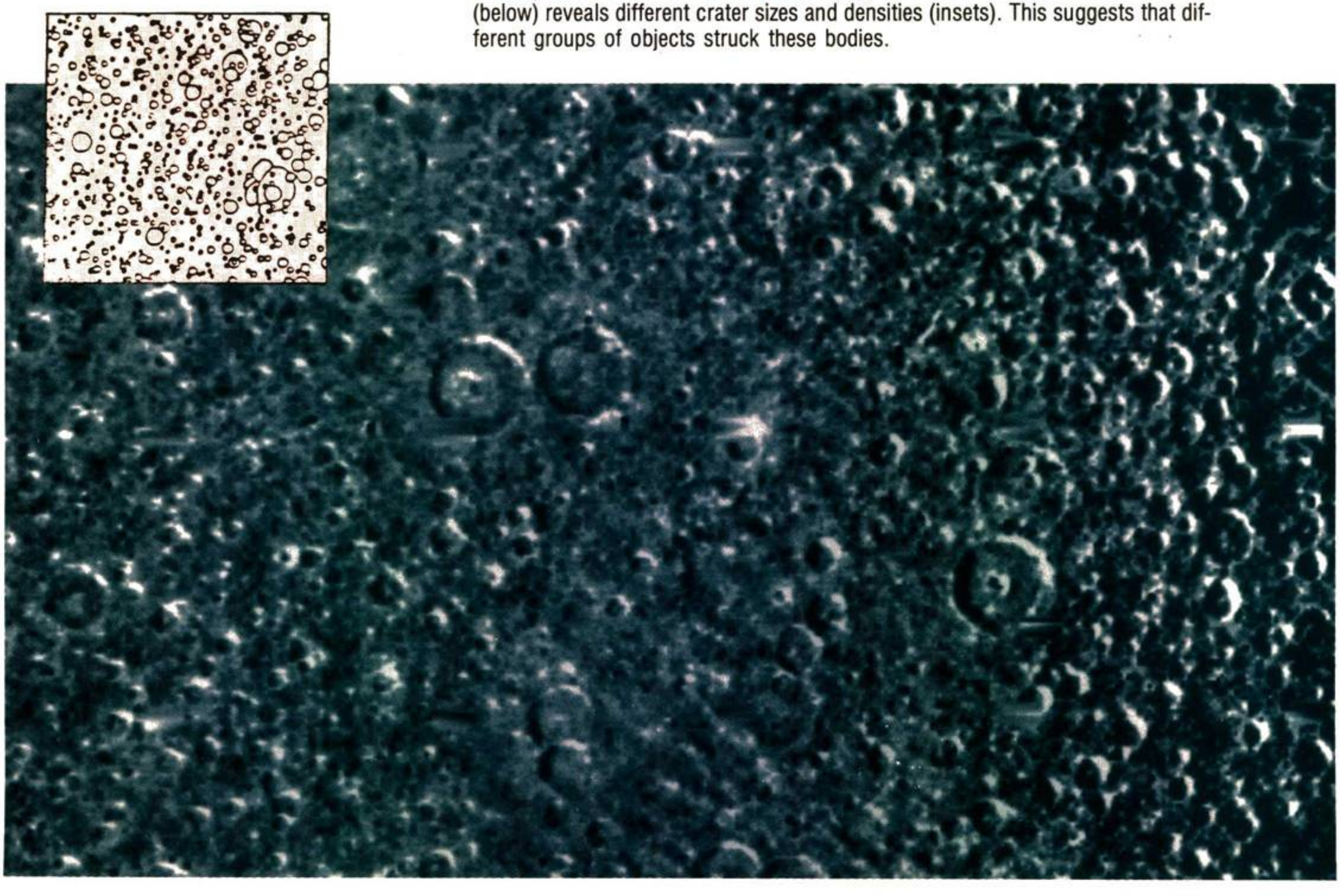
Voyager 2 images of the satellites of Uranus reveal evidence for several impact populations striking the surfaces of the satellites at different times. According to Robert G. Strom of the University of Arizona's Lunar and Planetary Laboratory, *Voyager* photos reveal evidence of different impact populations on all of the satellites.

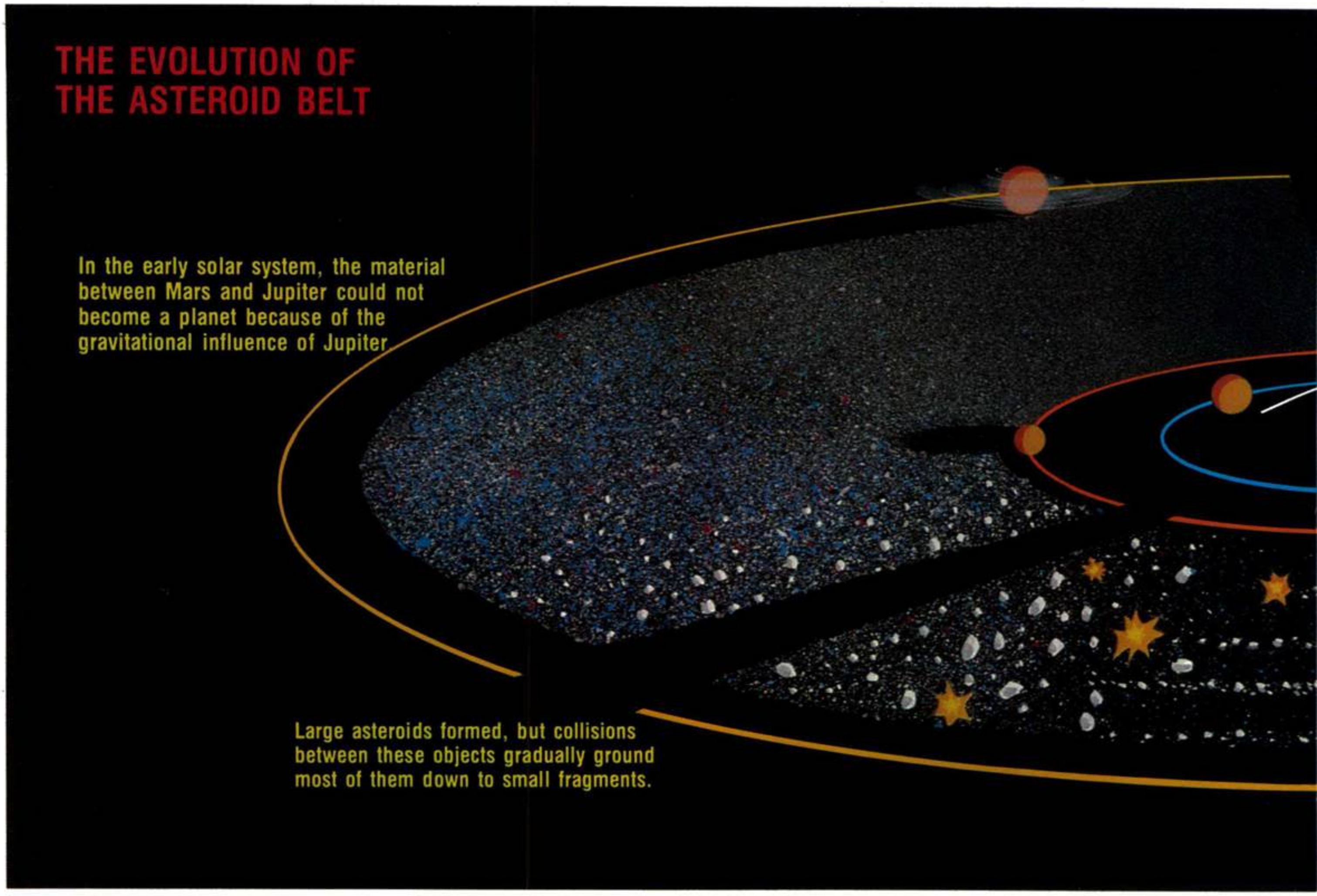
"There appears to be two different populations of impacting bodies in the inner solar system — one representing the more recent strikes by comets and asteroids and the other a period of early heavy bombardment. When you step out farther — take for instance Jupiter — the cratering statistics on Ganymede and Callisto differ from those in the inner solar system. This indicates that the size distribution of the objects that formed these craters is different from those that cratered the inner solar system. That must mean the impactors had a different origin."

The crater statistics for the satellites of Uranus and Saturn are also different from those for the other satellites and planets of the solar system. According to Strom, there were probably two families of objects involved. "In the inner solar system the objects were in heliocentric



A CRATER IS A CRATER IS A CRATER doesn't hold true across the solar system. A comparison of craters on the Moon (top) to those on Jupiter's moon Callisto (below) reveals different crater sizes and densities (insets). This suggests that different groups of objects struck these bodies.





THE EVOLUTION OF THE ASTEROID BELT

In the early solar system, the material between Mars and Jupiter could not become a planet because of the gravitational influence of Jupiter.

Large asteroids formed, but collisions between these objects gradually ground most of them down to small fragments.

orbits. But they were confined to the inner solar system and were probably leftovers from the accretion of the planets."

In the outer solar system, craters were probably formed by different populations, but it is questionable whether the objects were in a heliocentric orbit. "Otherwise, they should have been recorded on all the outer and inner members of the solar system," said Strom. "Since we don't see that, my best guess is that those objects were in orbits around each outer planet. These could be accretional remnants left over from the formation of the moons rather than the planets."

Many scientists believe planetocentric impactors existed and they cite Saturn's rings as an example. A planetocentric object would probably be large, because it formed as an accretionary remnant. And the object would be more likely to swing into a planet's or a satellite's path than a heliocentric object would because it formed in relatively the same plane. The unusual tilt of Uranus (Uranus' magnetic poles are displaced 55° from its geographic poles) and the large impact crater on Saturn's satellite Mimas may have been the results of major impact events by planetocentric objects.

But other scientists disagree with the existence of planetocentric objects, pointing out that there is really no good example of a planetocentric object in the solar system, at least none large enough to create huge craters.

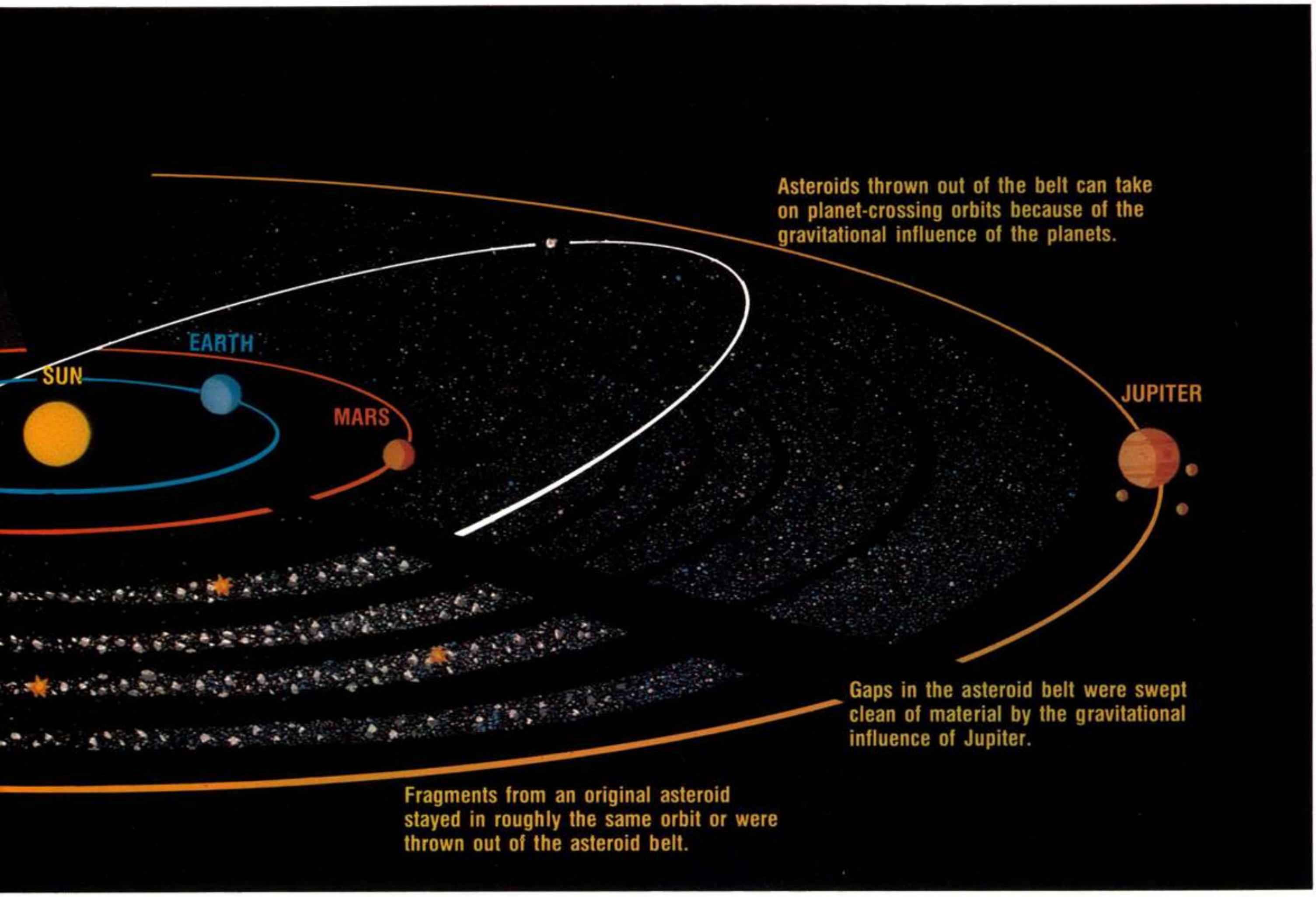
After the era of heavy bombardment ended, comets took over as the dominant source of impacting bodies in the solar system. A few scientists are even examining the role comets might have played in spreading life throughout the solar system. This theory, called panspermia, examines the idea that life could be spread from one planet to another by the movement of material. If organisms, or more likely bacteria, were within the top layers of a planet, they could find sanctuary within a large chunk of debris ejected from a planet after an impact. Protected from various harmful types of radiation, the bacteria could feasibly remain dormant for years.

Most scientists, however, disagree with panspermia and cite the difficult logistics of spreading such material to other planets, not to mention the unlikely probability that many planets possessed the exact conditions that would allow life to develop.

Recurring Cometary Bombardments?

Another question concerning comets that has received much attention recently is the frequency of cometary bombardments. If the impacts of comets on solar system bodies are not scattered randomly over time but occur at regular intervals, scientists would have a unique mechanism for probing both the outer reaches of the solar system and the evolution of life on Earth.

Many scientists suspect that there is such a periodicity to the impacts on Earth and have suggested several mechanisms that could be responsible for sending comets into the inner solar system. The Oort cloud, the domain of comets that stretches far beyond the planets, is thought to be perturbed periodically; estimates run from 26 million- to 32 million-year cycles. One possible mechanism is that our Sun has a dim companion star, aptly called "Nemesis." This star circles the solar system in a very eccentric orbit about once every 30 mil-


Asteroids thrown out of the belt can take on planet-crossing orbits because of the gravitational influence of the planets.
EARTH
SUN
MARS
JUPITER
Gaps in the asteroid belt were swept clean of material by the gravitational influence of Jupiter.
Fragments from an original asteroid stayed in roughly the same orbit or were thrown out of the asteroid belt.

lion years and perturbs the Oort cloud, sending comets toward the inner solar system.

Another theory points to a Planet X, an as-yet undiscovered member of our solar system believed to lie past the orbit of Neptune, that rocks the inner Oort cloud. There are complications with both ideas: the eccentric orbit of Nemesis would be very unstable and the star's orbit would decay before long, and Planet X would have to have an extraordinary orbit to produce a 30 million-year cycle.

Other scientists believe the solar system's up-and-down movement through the galactic plane is a more plausible explanation of periodicity. The Milky Way Galaxy is about 100,000 light-years across and only 6,000 light-years thick. The solar system is located on one of the Galaxy's spiral arms and, like many of the objects circling the central hub of the Galaxy, travels up and down through the galactic plane. Each time the solar system passes through the plane, there is an increase in gravitational pull from the dust and nebulae in the galactic disk.

This bobbing up and down occurs eight times in the Sun's 250 million-year revolution around the hub of the Galaxy. These are times when the Oort cloud could be perturbed by the increase in gravity, which would send comets toward the inner solar system.

Finding regularities in the entrance of Oort cloud comets into the solar system would be important. The entry of comets into the inner solar system could result in showers of comets that strike the Earth over a geologically short period of time. These showers may be responsible for many changes on Earth, from mass extinctions to the activation of various geologic processes.

Explaining Mass Extinctions

In 1980 Luis and Walter Alvarez at the University of California at Berkeley determined that a thin clay layer enriched with the metallic element iridium, an element found mostly in objects from space, corresponded with the Cretaceous-Tertiary boundary 65 million years ago. The Alvarez's proposed that a massive meteorite or comet struck the Earth which resulted in the mass extinctions of various flora and fauna, the most noticeable being the dinosaurs.

Since the Alvarez theory was proposed, other scientists have found numerous mass extinctions occurring with intervals ranging from 26 million to 30 million years that may have been caused by the impact of a comet. Besides iridium, the extinction layers also include small droplets of once-molten material called microspherules and shocked quartz and feldspar grains, both caused by the pressures and shock brought about by tremendous impacts.

But there are disagreements about the accuracy of dating objects such as fossils and impact craters. For example, in the case of the dinosaurs, some paleontologists have argued that the fossils of the ancient creatures are too sparse to determine whether the extinctions were gradual or abrupt. The dating of terrestrial craters is also controversial: many craters are very eroded or not easily identifiable as impact craters.

Asteroids have also played a role in the more recent impact history of the solar system. As objects from the main asteroid belt are perturbed by collisions within the belt and the influence of Jupiter, they can be thrown into orbits that put them on a collision course with the terrestrial planets.

What could cause periodic showers of comets from the Oort cloud? The Sun's unseen companion star? The pull of the Milky Way? Planet X?

Many planet-crossing asteroids have been discovered in recent years. If an asteroid wanders in an orbit that brings it inside that of Earth and occasionally crosses Earth's path, it is called an Apollo asteroid. If it passes the orbit of Mars and comes close to Earth, it is labeled an Amor asteroid. One of the rarest but potentially dangerous types of asteroids is the Atens. With an average distance from the Sun inside the orbit of Earth, Aten asteroids frequently cross Earth's path.

Pieces of Mars Thrown to Earth

But Earth is not the only planet threatened by the impact of these wayward asteroids. Mars-crossing objects may have struck the Red Planet within the last 180 million years. Recent studies of a certain group of meteorites, the SNC meteorites, have shown that these objects may have a possible Mars origin. In the 1950s, Harold C. Urey postulated that the SNC meteorites were ejecta from our own planet; by the 1970s speculation turned toward Mars.

Additional studies conducted by Ann M. Vickery and H. Jay Melosh of the University of Arizona's Lunar and Planetary Laboratory point towards a Mars origin. After determining the ages of the meteorites by analyzing how long they had been exposed to cosmic rays, scientists found evidence of three different ages: 10 million, 2.5 million, and a half-million years.

Vickery and Melosh's theory proposes that a single impact event occurred on Mars around 180 million years ago and excavated a crater at least 100 miles in diameter. The blast hurled debris up to 50 feet in diameter into space. Cosmic rays would have penetrated only the outer few meters of the rock; the inner material would have remained shielded. After a series of collisions with other space debris the smaller pieces would have been exposed. Thus, the various cosmic times age.

"The giant crater hypothesis does two good things," said Melosh. "It explains why you get big chunks, because it takes a big crater to get big chunks into escape velocity, and it explains why there are more Mars meteorites falling to Earth now than Moon meteorites. The total mass of lunar material that falls on the Earth is a hundred to a thousand times less than Mars material. This has always been puzzling because the Moon is closer and has a lower escape velocity. We are lucky enough to have had an impact on Mars in recent times that has temporarily flooded the inner solar system with Mars debris." But to date there have been no candidates for the impact crater on the planet Mars.

Watching for Earth-Crossers

Not content to just sit and wait for such an impact on Earth, astronomers have recently begun systematic searches of the sky for Earth-crossing objects. Two groups at the Palomar Mountain Observatory in California have been looking for these objects. One of the searches is conducted by Eleanor Helin, a research scientist at the Jet Propulsion Lab and the principal investigator of the Palomar Planet-Crossing Asteroid Program, which probes the skies with the 18-inch and 48-inch Schmidt telescopes on the mountain.

"Anyone who had worked on the 18-inch Schmidt occasionally reported a near-Earth asteroid," said Helin, "but there were never enough observations to run an orbit or predict a recurrence." Since 1973 Helin and other researchers and students from the California Institute of Technology have spent long nights at the telescope photographing the sky.

Back to back with Helin's group is the team of Carolyn and Eugene Shoemaker, who have been independently searching for asteroids since 1982. Eugene did extensive geologic mapping of the Barringer Meteor Crater in northern Arizona and was involved in mapping the lunar surface during the *Apollo* program. His interest in near-Earth asteroids is twofold: "We are trying to simultaneously look at the geological record of impact craters and what is in the sky as near-Earth objects. It is the comparison with the two sets of data that is very important."

Carolyn Shoemaker's work with near-Earth bodies uses an intensive method of scanning thousands of photographic plates stereoscopically. And the search has paid off: Carolyn has found more than nine new Earth-crossing asteroids and eight comets.

Another survey, the *Infrared Astronomical Satellite* Survey, has detected about 15,000 objects in the solar system. The survey, which has covered 96 percent of the sky, has found 2,400 known asteroids and 25 known comets. And at Kitt Peak Observatory in Arizona, the Spacewatch Camera has discovered 250 new asteroids.

But that may be only a drop in the bucket. So far fewer than one hundred Earth-crossers larger than one kilometer across have been discovered out of an estimated population of one thousand. Cataloging these objects is more than an exercise in precaution, however. As the population of known objects grows, scientists will be able to better understand where they came from and what the objects are made of.

In the view of some scientists, discovering more of these objects near Earth increases the likelihood that someday we will be able to turn the tables on the solar system and impact the impactors ourselves. Following flybys of Comet Halley, several missions to comets and asteroids are in the works. The Soviet Union is planning a mission to an asteroid that would probe an asteroid with the help of a rocket-powered penetrator (see "The Soviets Advance into the Solar System," page 36). The United States is considering a comet penetrator as part of its *Comet Rendezvous Asteroid Flyby* mission.

Such missions will determine whether asteroids are composed of materials that can be used as resources for construction and life support in space. Having these resources at hand in orbit could greatly reduce the cost of many types of space missions.

These encounters with potential impacting bodies may be the stage in the chronology of planetary bombardments that we will be able to watch in our lifetimes. □

Patricia Barnes-Svarney has written for Air & Space, Odyssey, *and the American Geological Institute's* Earth Science. *She holds a masters degree in geography/geology from the State University of New York.*

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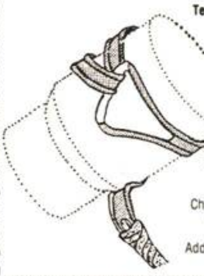

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Anatomy of a COSMIC JET

Close-up views of M87's jet give astrophysicists a new perspective on the nature of cosmic jets.

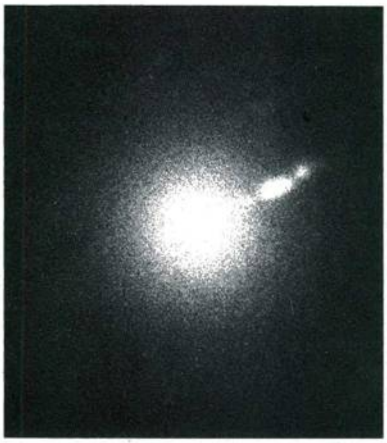
by Jeff Kanipe

It's not too unusual for astronomers to study images of celestial objects or fresh data on a stack of computer print-outs and just not recognize what they're looking at. Decoding the universe's more challenging enigmas sometimes takes a new instrument or a new way of understanding.

Such was the case in 1918 when astronomers first detected the curious bright ray of light projecting from the nucleus of the giant elliptical galaxy M87. Little did astronomers know that what they were looking at would become one of the most intriguing features in galactic astronomy.

The M87 jet, as it came to be called, could be photographed, but little more than a narrow ray of bluish light made up of a few brighter blobs was revealed on photographs. Interpretation of the jet had to wait for the invention of radio astronomy, radio telescope arrays, and supercomputers.

For the past several years the combined resolving power of the twenty-seven radio antennae that constitute the Very Large Array (VLA) near Socorro, New Mexico, plus advanced signal processing and image enhancement techniques, have been used to observe the M87 jet. An analysis of images produced during these observations was conducted by Frazer Owen and Tim Cornwell of the National Radio Astronomy Observatory (NRAO), Philip Hardee of the University of Alabama, and Dean Hines of New Mexico Tech. As a result of their analysis, a better idea of the jet's structure has emerged.



THE JET SHOOTING OUT OF M87 has fascinated astronomers for seventy years.

Cosmic jets are thought to arise from a supermassive, compact object at the center of a galaxy or quasar — probably a rotating black hole with a mass of several billion suns. According to current theory, gas spiraling in toward the black hole becomes compressed and superheated. Much of the gas falls into the black hole, but the rest is discharged along the poles of the hole, either squirted out by radiation pressure in the disk or caught up in magnetic field lines issuing from the black hole. These whirling magnetic field lines act like eggbeaters, churning out gas at very high velocities.

The images produced during the VLA observations show detail down to 0.1 arcsecond, which means that features 25 light-years across at the distance of M87 can be resolved. Such resolution — ten times better than with ground-based optical telescopes — has revealed a complex series of twists, shocks, and filaments that appear to lie not throughout the jet, as had been assumed, but *on the surface* of the jet.

Among well-observed radio galaxies and quasars, jets are not uncommon features: hundreds have been cataloged in a variety of configurations. Some are complicated in appearance, such as the "twin-tail" jet associated with the central galaxy in the Abell 400 cluster; others, like the dual jets emerging from the elliptical galaxy 3C 449, are strikingly symmetrical.

What distinguishes the M87 jet from all other jets, however, is its proximity to our Galaxy. Lying only 55 million light-years away, the M87 jet is the nearest known jet observable from the Northern Hemisphere. This makes it the most accessible for detailed study.

"M87 is very close by galactic standards," said Frazer Owen, a radio astronomer at NRAO. "Most of the jets we know about are several hundred times more distant, so we can't see as much detail."

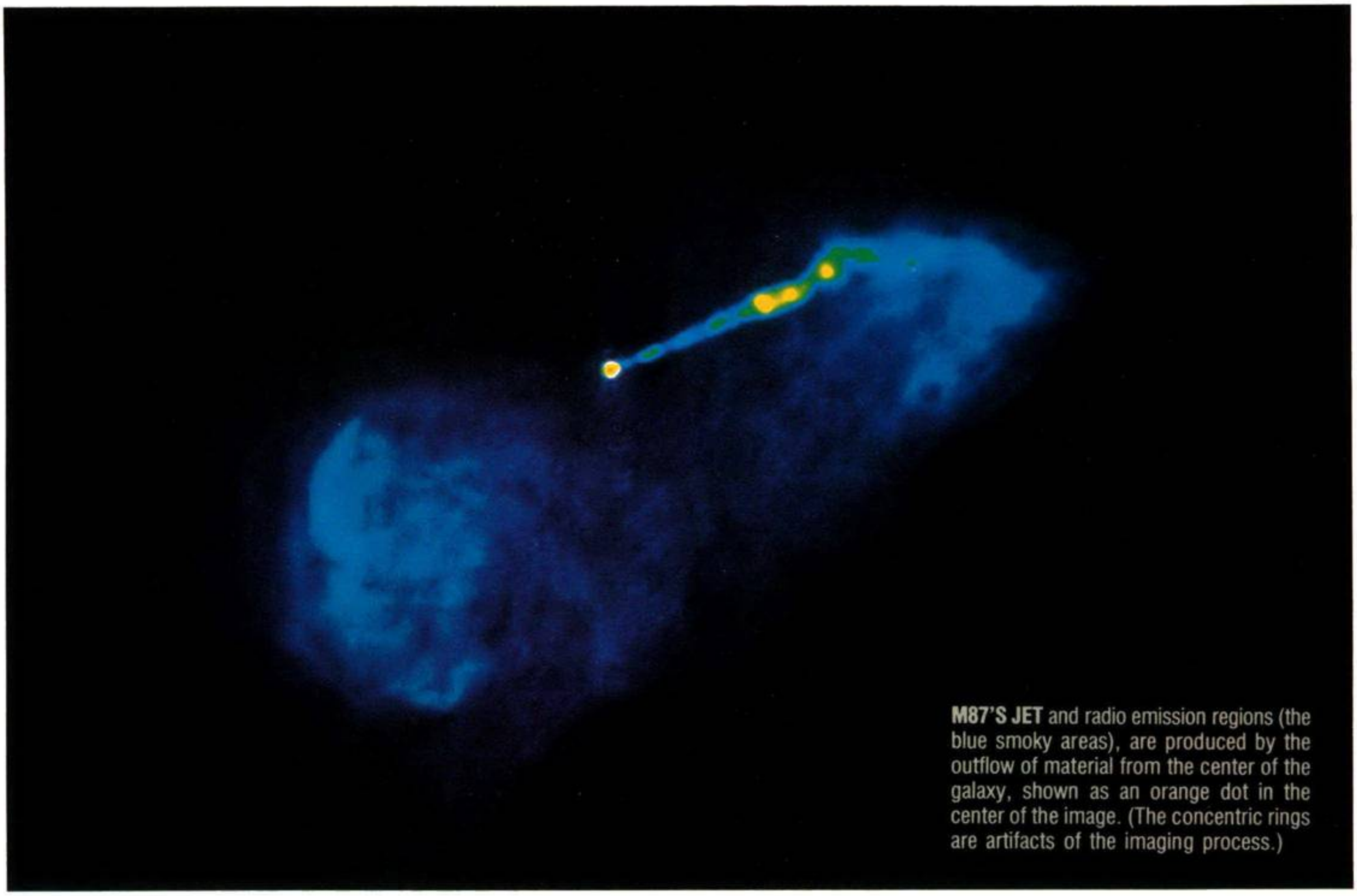
One of the most important results learned from the VLA observations is that the interior of the jet may be hollow. Instead of being "filled" with hot, rapidly flowing material, the jet may be a nonradiating conduit for high-energy electrons rushing out of the galaxy's nucleus. Optical and radio emission would be produced when the electrons encountered the boundary between the jet and the denser interstellar medium.

"We're not looking at a filled structure, which is the way people have thought of jets up until now," said Frazer Owen, a member of the team of astronomers that generated and analyzed the images. "We're looking at something where only a small volume that you see in projection is filled with emission. Most of the emission seems to be happening on the surface of the jet in a thin boundary region."

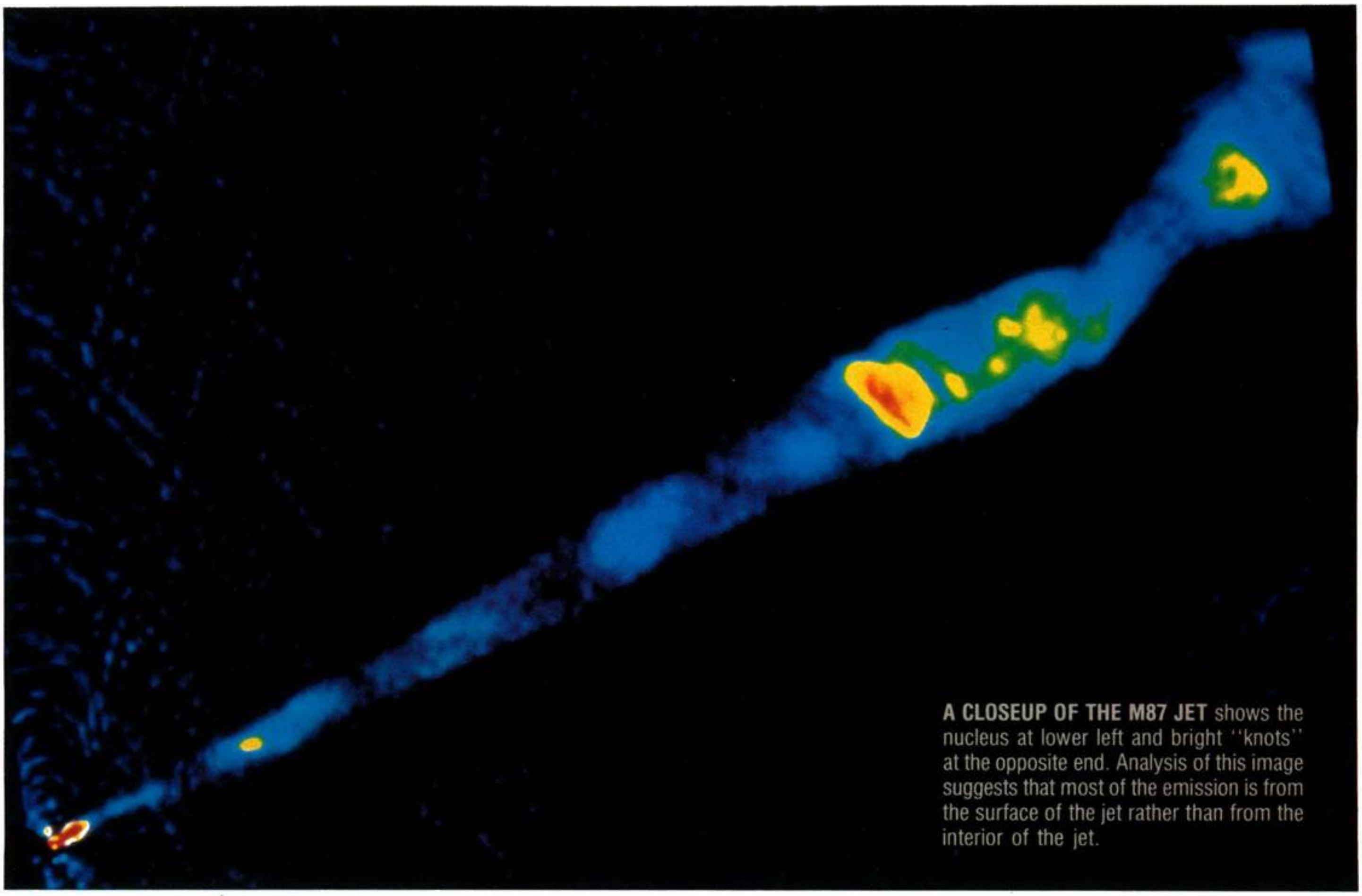
Where the Jet Gets Its Glow

If the M87 jet is indeed a nonradiating cylinder sheathed in a luminous layer of discharging electrons, a new theory of the processes leading up to the jet's emission is required.

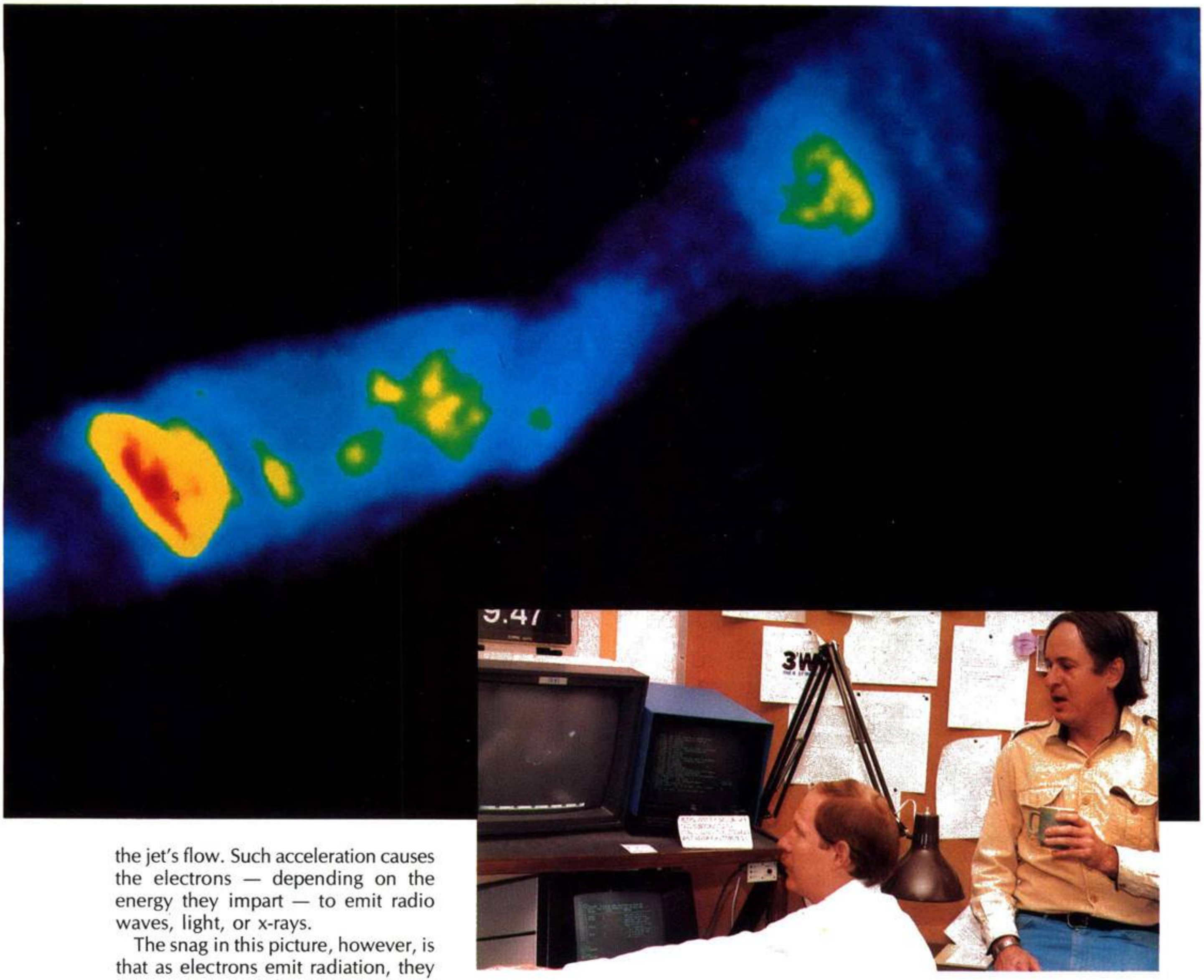
Radio and optical observations have established that both the nucleus and jet of M87 emit synchrotron radiation, a type of electromagnetic radiation derived from high-energy electrons. The synchrotron process begins when electrons, captured in the powerful magnetic field generated by the black hole, are accelerated to near-light speeds on spiral paths around magnetic field lines, which lie parallel to



M87'S JET and radio emission regions (the blue smoky areas), are produced by the outflow of material from the center of the galaxy, shown as an orange dot in the center of the image. (The concentric rings are artifacts of the imaging process.)



A CLOSEUP OF THE M87 JET shows the nucleus at lower left and bright "knots" at the opposite end. Analysis of this image suggests that most of the emission is from the surface of the jet rather than from the interior of the jet.



KNOTS AND TWISTS in the outer region of the M87 jet may actually be features on the surface of the jet rather than features occurring throughout the inner portion of the jet. The shape of the bright knot at lower left suggests that the knot has a helical structure. Note the "mushroom" feature at upper right. These images were processed by a team of astronomers that included Philip Hardee (seated) and Frazer Owen.

the jet's flow. Such acceleration causes the electrons — depending on the energy they impart — to emit radio waves, light, or x-rays.

The snag in this picture, however, is that as electrons emit radiation, they lose energy, and the more energetic electrons are, the faster they lose that energy. Electrons producing radio energy have lifetimes of a few hundred years, while those producing visible light may last twenty or thirty years.

So how can jets thousands of light-years long be bright at the *far* end of the jet when the particles producing the radiation have lifetimes too short to travel that far?

The prevailing explanation has been that some disturbance re-energizes the electrons along the jet path, either shocks produced when newly ejected hot gas encounters cooler, slower-moving gas or turbulence between the jet and the interstellar medium. Both ideas may have to be modified.

"The possibility exists," said Owen, "that there are relativistic particles in the center of the jet that are not in any sort of magnetic field and just aren't radiating at all but are moving out in the center of the jet without losing energy until they hit the boundary layers and radiate there."

Owen said it is still too early to tell whether or not the M87 insights will help astronomers understand the nature of jets in other galaxies. For instance, though it is over 6,000 light-years long, the entire M87 jet is actually embedded in the center of the visible disk of the galaxy, where other phenomena may influence the behavior of the jet.

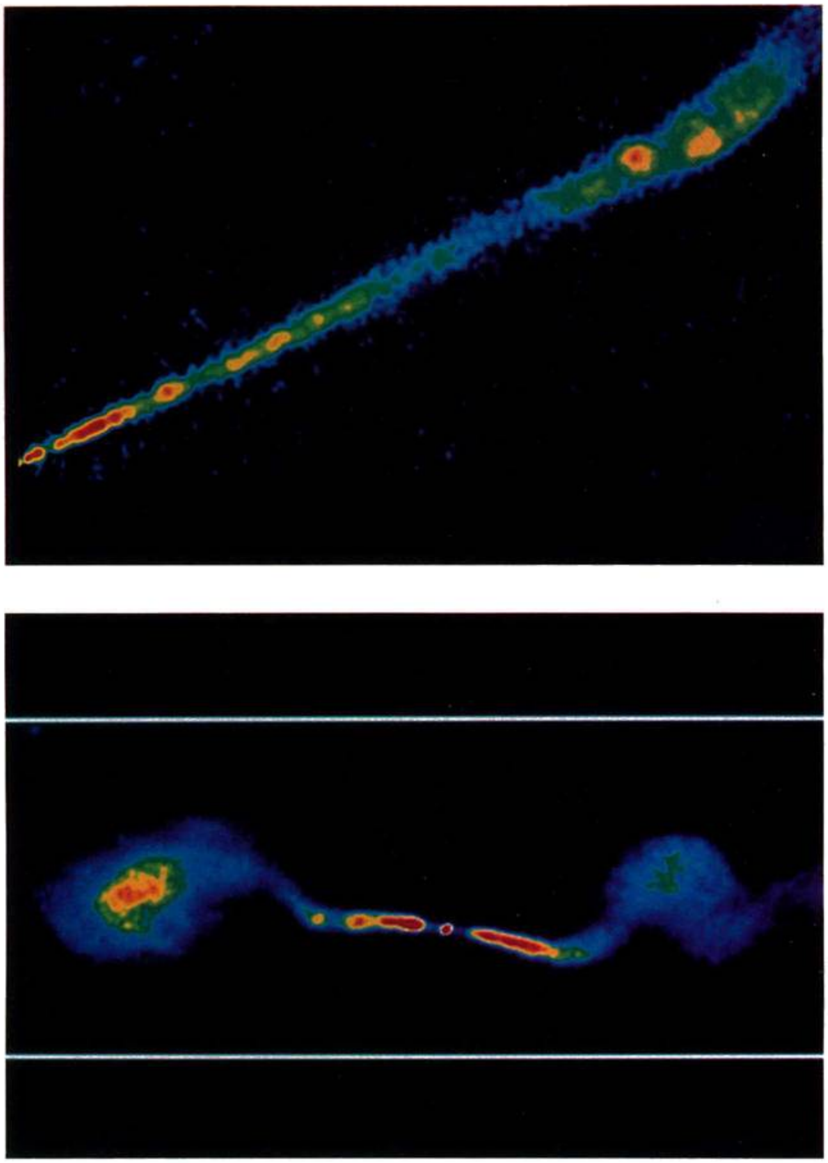
"We don't know whether the M87 jet is necessarily representative of all the things going on in bigger jets," said Owen. "Jets farther away [from us] are much bigger structures than the M87 jet, one hundred times bigger. This means those jets have propagated much farther from the nucleus into a much less dense medium where there are much lower pressures involved."

Supercomputer Simulations

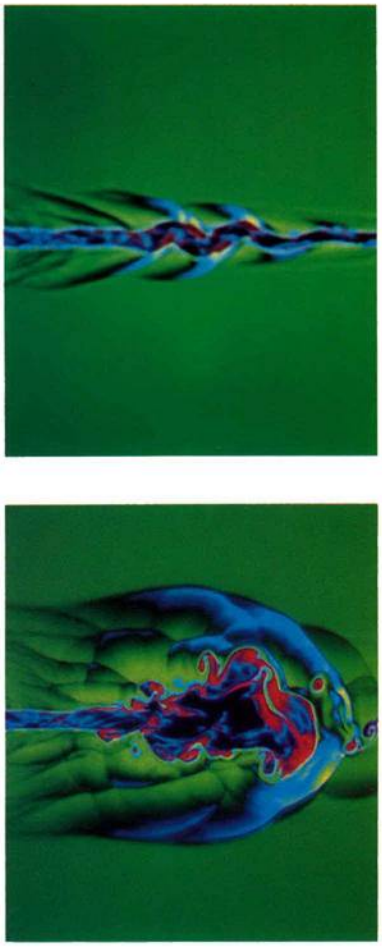
The complex nature of cosmic jets has sent many astronomers to supercomputers in an effort to understand how such phenomena might form and evolve. Philip Hardee of the University of Alabama and a member of the image analysis team has been using the supercomputer at the University of Illinois Supercomputer Center in Champaign to generate two-dimensional images of the effects of instabilities in hypothetical jets. In particular Hardee wants to know why jets are kinked in places.

"When you look at most jets," said Hardee, "they look disturbed in some way. We're ultimately after an explanation of why they look disturbed."

Although Hardee's program is not based on any specific jet, Hardee said the velocity of the flow used in the program approximates that of the M87 jet. Essentially the program shows what



THERE ARE NO TYPICAL JETS. A narrow, straight flow emerging from NGC 6251 (top) is over 400,000 light-years long. The dual jet system from the radio galaxy 3C 449 (above) exhibits almost mirror-image jets and lobes.



COMPUTER SIMULATIONS of jets indicate that slight "wiggles" at the nozzle disrupt the flow. In the top image a jet (blue band) pushes through a denser medium (green field). Small wiggles grow until they form a lobe at the outer end of the flow (above).

happens when a jet shoots through a medium that is slightly denser than material in the jet itself. The jet's velocity is highly supersonic — that is, the speed of the jet is much faster than the speed of sound in the gas. To introduce instabilities in the flow, the jet's "nozzle" is wiggled slightly.

The results show that slight wiggles in the nozzle produce instabilities that grow in magnitude until the jet breaks apart and builds up a broad region of material at the opposite end of the nozzle.

This feature of the model corresponds to a feature commonly observed with jets: the radio lobe. Radio galaxies have extended regions of strong radio emission on opposite sides of their visible disks. Such lobes, which cannot be detected optically, are nearly always associated with a jet. Quizzically, though, many radio galaxies have strong radio lobes but don't appear to have optical jets. This is yet another conundrum that astronomers must eventually resolve.

However, on a fundamental level, Hardee said, these results mark a good beginning toward understanding some basic ideas about jet flow. Although the program does not attempt to reflect the reality of "hollow" jets, Hardee believes the best approach is trying to understand the roles density and velocity play in forming jet structures before attempting more realistic models.

"We want to understand the simple case first," Hardee said. "We want to know how far a jet will go before it breaks up and forms a lobe and how that [breakup] is a function of the jet's speed."

It will most likely be some time before the VLA's high-resolution images of the M87 jet are bested. Nevertheless, the prospects for future observations are encouraging. The Hubble Space Telescope, when it is finally in operation in mid-1989, may be able to resolve some of the stars near the core of M87 and help astronomers deduce whether or not matter is swirling about a supermassive object. In addition, it is possible that high-resolution radio observations compiled over a decade or two may show changes in the large-scale features of the jet. The differences in the positions of jet structures should allow astronomers to derive a more accurate value for the velocity of the jet.

It took over half a century for astronomers to recognize cosmic jets for what they are — manifestations of extraordinary activity at the centers of galaxies and quasars. Now we have a new way of looking at the structure of jets that could lay the groundwork for future discoveries. Perhaps another ten years of research will see us closer to understanding how jets work and — that secret of secrets — what powers them. ☐

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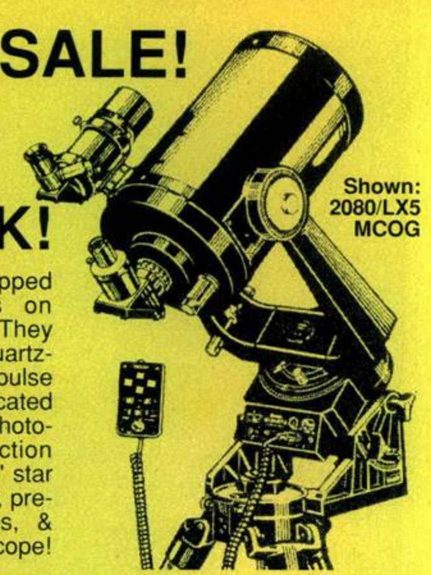
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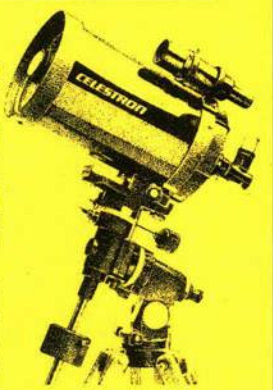

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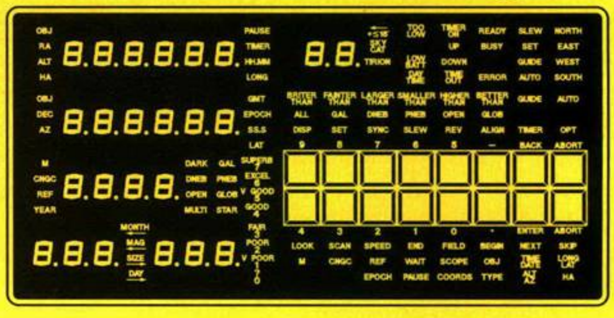

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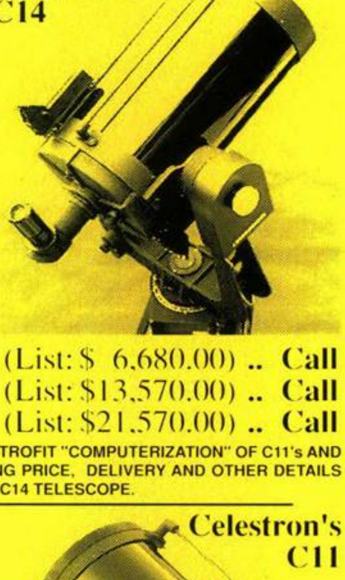

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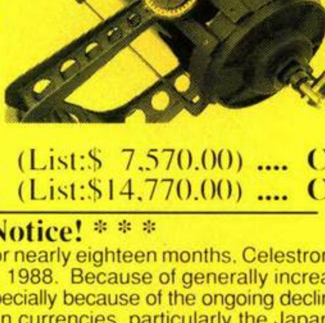

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The Soviets Advance into the Solar System

Mars and the asteroids are targets for systematic Soviet exploration by orbiters, rovers, and sample-return missions.

by Donald F. Robertson

Like some contraption out of a Victorian science fiction novel, a giant balloon strains toward the pink morning sky, tethered above an upside-down, metallic-colored bag. The bag in turn is anchored to an instrument-studded gondola resting on the red floor of a Martian desert.

The Sun rises over mountains on the horizon and heats the thin air trapped in the bag. The bag lifts the gondola and the three-part machine rises majestically into the dust-filled sky. The wind catches the craft, and the craft swoops over the Martian landscape. Throughout the day cameras record the scenery below and send the images to an orbiting relay station.

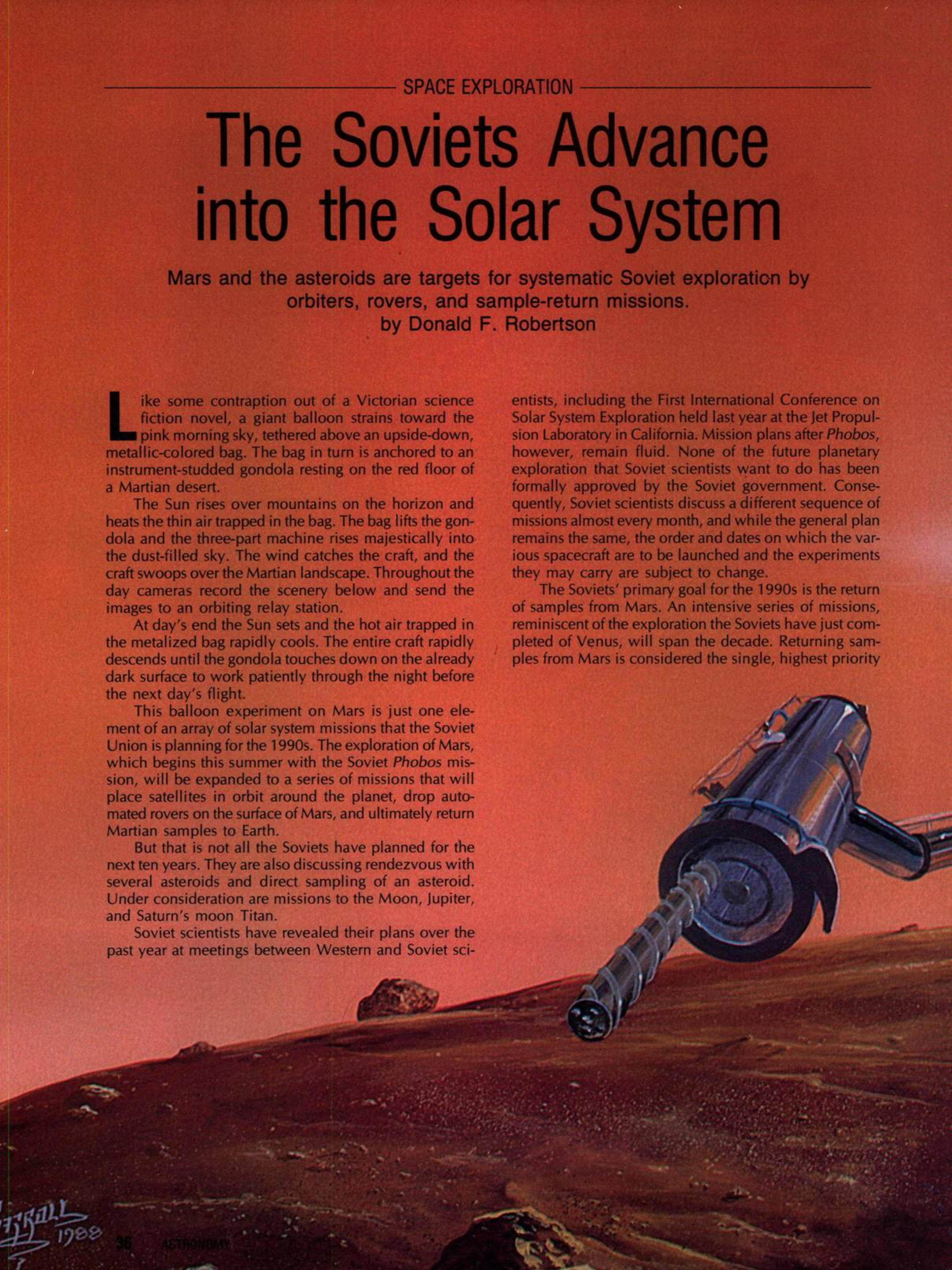
At day's end the Sun sets and the hot air trapped in the metalized bag rapidly cools. The entire craft rapidly descends until the gondola touches down on the already dark surface to work patiently through the night before the next day's flight.

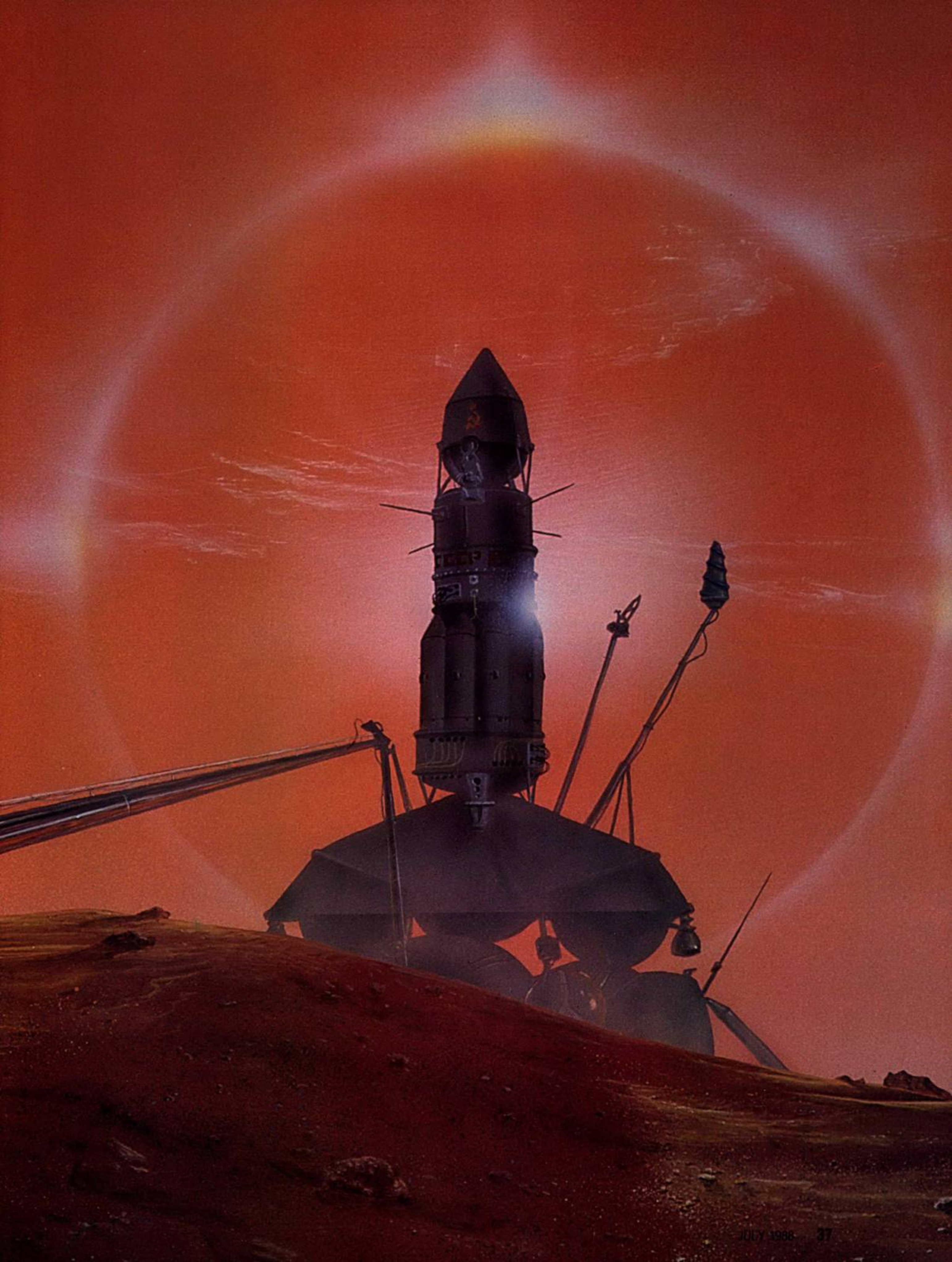
This balloon experiment on Mars is just one element of an array of solar system missions that the Soviet Union is planning for the 1990s. The exploration of Mars, which begins this summer with the Soviet *Phobos* mission, will be expanded to a series of missions that will place satellites in orbit around the planet, drop automated rovers on the surface of Mars, and ultimately return Martian samples to Earth.

But that is not all the Soviets have planned for the next ten years. They are also discussing rendezvous with several asteroids and direct sampling of an asteroid. Under consideration are missions to the Moon, Jupiter, and Saturn's moon Titan.

Soviet scientists have revealed their plans over the past year at meetings between Western and Soviet scientists, including the First International Conference on Solar System Exploration held last year at the Jet Propulsion Laboratory in California. Mission plans after *Phobos*, however, remain fluid. None of the future planetary exploration that Soviet scientists want to do has been formally approved by the Soviet government. Consequently, Soviet scientists discuss a different sequence of missions almost every month, and while the general plan remains the same, the order and dates on which the various spacecraft are to be launched and the experiments they may carry are subject to change.

The Soviets' primary goal for the 1990s is the return of samples from Mars. An intensive series of missions, reminiscent of the exploration the Soviets have just completed of Venus, will span the decade. Returning samples from Mars is considered the single, highest priority





Returning Martian soil to laboratories on Earth is the ultimate goal of Soviet Mars exploration in the next decade.

for that planet by scientists in both the United States and the Soviet Union. The last Mars mission, the U.S. *Viking* mission in 1976, which analyzed the Martian soil in a minilaboratory in the spacecraft, failed to resolve the question of whether there is life on Mars.

To answer that question and others about the chemical history of Mars, both Soviet and American scientists now believe samples must be brought back to a terrestrial laboratory. On Earth, scientists can probe the samples with all the instruments of modern science instead of having to design a few automated experiments around preconceived notions of what conditions and any life on Mars must be like.

The only other alternative is sending the laboratory and scientists to Mars, something both countries are considering. But before manned bases on Mars could be established, we would have to learn to "live off the land" so that the costs of transporting people to Mars and supporting them on the planet could be reduced as far as possible. A sample-return mission would provide detailed knowledge about the Martian soil and any resources it may contain, which could make later human missions simpler, safer, and much cheaper.

Multiple Mars Sites Needed

The scientific rationale for the huge scale of the Soviet Mars missions was presented at the solar system conference by Valery L. Barsukov, director of the Vernadsky Institute of Geochemistry and Analytical Chemistry in Moscow. "It is impossible to study the chemical characteristics of Mars from a single point, but it is possible to do so from three or four points. It is not easy to find satisfactory landing sites which could give answers to some, if not all of our science questions," said Barsukov.

"How many sites would we need to sample to get a good chance of finding paleobiology? One can search for paleobiological activity in sedimentary deposits in riverbeds and their mouths. We also have to go to the edge of the polar caps to get a sufficiently long column of ice to measure the isotopes and elements in the ice. And the search for life needs to be conducted at the very uppermost part of the permafrost which periodically melts and refreezes," said Barsukov.

"Even two rovers cannot answer all the questions. So with our American colleagues we need to plan different sites or send a large number of rovers."

The search begins in either 1992 or 1994 when two interplanetary spacecraft lift off on Proton launch vehicles from the Soviets' launch site in central Asia. After being checked out in Earth orbit for a few hours, each Proton's escape stage ignites to boost the spacecraft, which weighs as much as 13,200 pounds, toward Mars.

Once there, the main spacecraft dip into the atmosphere to slow into orbit, protected from friction by a large aeroshell. Each spacecraft releases two-part landing craft protected by heat shields. Rockets slow the landers and the landers fall toward the planet's thin atmosphere. Parachutes open to slow the landers to subsonic velocity. When the landers reach the surface, the lower portion of each lander immediately separates, releasing the French-made atmospheric balloon.

Each "balloon" is actually made of two distinct inflatable bags. On top is a 4,000-cubic meter gas balloon of very thin, raw polyester that weighs only 24 pounds. Upon release from the lander, this balloon takes about one-and-a-half minutes to inflate with helium. Suspended below the balloon is a 6,000-cubic meter "montgolfiere," an open-air parachutelike enclosure made of aluminized or gold-plated polyester that weighs only 30 pounds.

The system is very simple in theory. During the night when the air in the montgolfiere is cool, the gas balloon is not quite buoyant enough by itself to lift the gondola with its experiments off the Martian surface. It is, however, buoyant enough to support itself, the montgolfiere, and more than 300 feet of cabling safely above the rugged desert. As morning Sun heats the air trapped in the montgolfiere, the balloon gains buoyancy until both enclosures together can lift the gondola. This should happen at about six o'clock in the Martian morning.

The entire contraption slowly ascends until around nine o'clock, after which it drifts at a constant altitude of half a mile to a mile. During the day a visible and infrared camera and an infrared spectrometer photograph the Martian desert below. Each balloon's camera transmits detailed images to the orbiters. Resolution should be as good as one centimeter, which would detect objects the size of a watch sitting on the desert.

Photographing Mars from a Balloon

Depending on where the wind blows the balloons, the photographs relayed to Earth may show spectacular Martian river valleys and volcanoes from angles impossible to see from orbit. Photos could even be taken from inside the canyons or, as the balloons ride updrafts, swooping over a vast volcanic caldera. Meanwhile, the infrared instruments measure the temperatures of the rocks below and, by looking at the way those rocks absorb the Sun's heat, analyze the chemical structure of the rocks.

According to V. Linkin of Moscow's Institute for Space Research, the reason Soviet scientists and their French collaborators are using such a complex, double-balloon design is that the balloons can be controlled without releasing irreplaceable helium. Martian air is released from the montgolfiere to control altitude, while the upper balloon remains completely inflated. So a balloon with a limited supply of helium and thus light enough to get to Mars can function for long periods of time. The balloons may achieve five or six day/night flight and landing cycles — although the balloon designers hope for ten or more — before too much helium leaks through the enclosed balloon's plastic walls and the balloon can no longer provide its share of the lift.

Linkin believes it may be possible for the gondola to land at several locations during the day as well as at night and to leave small science packages at some of the landing sites. He hopes the U.S. Deep Space Network

As the spacecraft flies by the asteroid, a rocket-powered probe is fired into the asteroid to find out what it is made of.

antennae can help track the balloons so scientists can tell where each landing site was and correlate individual photographs taken from the air to Mars as a whole.

At around five in the evening the montgolfiere begins to cool and fall. Descent is relatively fast and the gondola strikes the surface at a hard seven to thirteen feet per second. T. Tarrieu of the French national space agency, the National Committee for Space Research (CNES), which is designing the balloon, said, "We are not sure how to deal with that at the moment," but designers are considering a flexible gondola that drags across the desert like a rope. This "snake" gondola is hollow with instruments inside.

During the night on the Martian surface one of the instruments, a gamma-ray spectrometer, measures natural gamma rays emitted by the surface material. Scientists can relate the frequency of detected gamma rays to the primordial radioactive materials that emitted them.

Steve Homann, a physicist at the Lawrence Livermore National Laboratories, said, "I can go out of my office and set a gamma-ray spectrometer on the ground and detect gamma rays emitted by radioactive elements that date from when Earth was formed." A detector crystal turns some percentage of these gamma rays into electrical signals, which are proportional to the energy of the gamma rays. Because each radioactive element emits gamma rays at a unique frequency, scientists can determine which elements emitted the gamma rays.

Another instrument in the gondola, a fluorescence x-ray spectrometer, also studies the the chemical makeup of the soil. The instrument bathes the ground in high-energy protons, which excite the inner orbital electrons of materials in the Martian soil to a higher energy. The electrons immediately fall back to their normal positions, emitting x-rays at a unique frequency. Matching that frequency to known frequencies of nonradioactive materials tells scientists what the Martian surface is made of.

A magnetometer measures the magnetism of Martian rocks. Because rocks can retain a remnant of an ancient magnetic field, these measurements tell scientists what any Martian magnetic field may have been like in the past. That in turn can indicate how active a planet Mars might have been.

Some scientists foresee a number of problems with using balloons to explore Mars, however, including the balloon's sensitivity to the wind. The vehicle is unguided, so what if the balloon landed in an area that is in shadow all or most of the day? How could the Sun heat the montgolfiere, which allows it to lift off again? Tarrieu believes that as French scientists have not yet been told where their balloons will arrive on Mars, it's too early for them to plan for such contingencies.

Mini-Rovers Roam the Surface

Meanwhile, back at the landers, miniature rovers drive down ramps to the floor of the desert. Barsukov said the rovers are very small with a scientific payload of only 55 pounds. Nonetheless, they have cameras for panoramic photography at a number of locations and surface experiments similar to those on the balloon gondolas. The range of each nuclear-powered rover is about 75 miles.

Another experiment being considered for the rovers involves what Barsukov calls "vibro-penetrators" to dig below the soil's zone of oxidation. The surface of Mars is heavily oxidized — rusted — which gives it a reddish color. Many Soviet scientists believe this oxidation caused the ambiguous results of the *Viking* landers' life science experiments. Organic compounds cannot survive in an environment as oxidized as Mars' upper soil layer, yet oxidized soil can be chemically active, which would confuse automated biological experiments. Barsukov believes the penetrators may dig 65 to 100 feet below the surface.

While all this is happening on the Martian surface, the orbiters photograph the planet with state-of-the-art, high-resolution cameras. The Soviets told American scientists at last year's Lunar and Planetary Science Conference in Houston that they hope to carry a synthetic aperture radar to image the Martian surface — and even a few centimeters below it — with a resolution of as little as ten meters. A synthetic aperture radar uses spacecraft motion to synthesize an "imaginary" antenna much larger than one that could be carried to Mars. The radar can tell much more clearly than cameras can what parts of the landscape lie on top of others, indicating which is older.

This complex and expensive mission is intended to explore areas on Mars that are being considered for an even more ambitious multiyear project to follow. That project, the return of Martian samples, will be carried out in three separate stages: placing rovers on the surface to collect samples, getting the samples from the surface into orbit, and sending the samples back to Earth.

Three Steps to Sample Return

The process begins in 1996 or 1998, two to four years after the balloon mission is launched. Two Proton launch vehicles lift for orbit. A year later much larger rovers descend to Mars. Each rover weighs 1,500 to 1,750 pounds, with 300 pounds of scientific payload.

While traveling up to 300 miles across Martian deserts, these craft photograph the landscape. Earthbound television watchers might expect to see a different scene every day. At several widely separated stops the robot vehicles collect soil and rock samples. They have up to two years for their traverse.

Once the samples are collected, the rovers find a flat desert and wait. Less than two years later, two spacecraft that will take the samples home to Earth arrive in a 300-mile orbit around Mars. These ascent vehicles have thirty to sixty days to find the old rovers on the surface. Each rover has a radio beacon, and once the ascent spacecraft have pinpointed the beacons, they drop out of orbit and land as near as possible to the rovers.

The ascent vehicles have small rovers of their own with a range of several tens of miles. They are to collect a limited sample in case the old, large rovers cannot be found in the vast Martian wilderness.

Assuming the old rovers can be found and activated to rendezvous with the ascent vehicle, the samples from the old rovers are transferred to the ascent vehicles. The latter immediately lift off and enter a 300-mile orbit, where they wait to be picked up in the final stage of the sample-return mission.

Missions to the outer solar system — where no Soviet spacecraft have ever ventured — are also being considered.

Two Earth-return vehicles are launched from Earth either in the same launch window as the ascent vehicles or two years later. The return craft enter a Martian orbit of 340 miles and look for the ascent vehicles, hopefully still orbiting below.

When the ascent craft are found, the return vehicles lower their orbits to rendezvous and dock with the ascent vehicles. This is a technique the Soviets have had a lot of practice with in the routine docking of automated tankers to the Salyut and Mir space stations.

Capsules containing the samples are transferred to the return vehicles. These spacecraft abandon the ascent craft in Mars orbit and then head home.

Once the return vehicles reach the vicinity of Earth, they decelerate into orbit and maneuver to a Soviet space station. Here, probably in a specially launched module, the samples are tested for biological and chemical safety. Once they have been declared harmless, the first samples from another planet are brought to Earth for distribution to scientists. The total sample return is expected to range somewhere between 1 and 6 pounds.

Penetrating an Asteroid

Mars isn't the only solar system body on the Soviet wish list. Barsukov outlined planning for a Soviet/French mission to the asteroid belt, hopefully with other European participation. Roger Bonnet, director of scientific programs for the European Space Agency, said ESA was approached by France in 1985 and is now considering overall European participation in the asteroid mission.

Current plans are for a 1994 launch of two spacecraft, possibly one French and one of European design or, as an alternative, both based on the Soviet *Phobos* craft. Issac Revah, director of programs for the French space agency, said CNES hopes to design its first interplanetary spacecraft for the asteroid mission and expects formal approval from the French government this year. Barsukov added that the Soviets are already discussing trajectory designs with the French.

The mission will carry several instruments to study the chemical makeup of an asteroid. A. Ammar of CNES anticipates two, three-axes stabilized spacecraft based on a communications satellite design. A scan platform points instruments at the asteroid, including wide- and narrow-angled cameras. A radar takes images just below the surface while the spacecraft is tracked to measure the asteroid's gravity field, indicating what the body is like deep inside.

The most exciting experiment is a rocket-powered probe designed to penetrate the surface of an asteroid. The penetrator is released during flyby. It ignites its rocket and accelerates to hit the asteroid at about 300 feet per second. The impact buries the penetrator's tip deep underground. Gamma-ray and x-ray spectrometers, similar to those on the Martian balloons, measure what the asteroid is made of. An upper portion remains overhead, which contains antennae to communicate with Earth and cameras to photograph the surface around the impact site.

Scientists want to explore a number of different kinds of asteroids. Given a 1988 approval leading toward a 1994 launch, Ammar hopes flybys of at least two large asteroids — probably 4 Vesta and 1 Ceres — can be achieved at speeds of less than 2.5 miles per second. Two medium-sized asteroids, one of carbonaceous and one of stony composition, and two small asteroids, including a Mars-crosser, have progressively lower priority. Successful flybys of all these targets should provide scientists with the largest possible cross section of what the asteroid belt as a whole is like.

To the Outer Planets?

At this point the Mars and asteroid missions are the top items on the Soviet list of solar system exploration priorities. Lower on the priority list is a lunar polar orbiter mission, called *Selena,* would study the mineralogical composition of the Moon. The lunar orbiter is intended to scout landing sites on the Moon for future sample-return missions. However, the Soviets have not discussed these beyond mentioning that one is to return samples from the far side of the Moon. No spacecraft has yet landed there, so that half of the Moon may well contain some surprises.

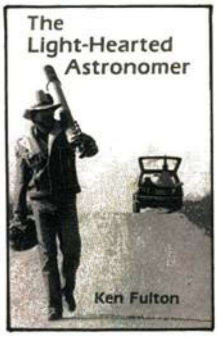
More ambitious and costly missions to the outer planets — where no Soviet craft has ventured so far — are also in the air. The Soviets have indicated an interest in atmospheric probes of Jupiter, Saturn, and Saturn's moon Titan. It is not clear, however, how serious the Soviets are about outer solar system missions because these missions are far beyond any spacecraft reliability the Soviets have demonstrated to date.

One of the biggest questions remaining about Soviet plans for the 1990s is the degree to which the United States will be involved. Although the two countries have not yet committed themselves to any joint missions, there is growing interest among scientists on both sides to work together at least on the most complex mission: the exploration of Mars. Roald Sagdeev, director of the Institute for Space Research and dean of the Soviet space program, has publicly proposed such joint efforts.

But whether such informal cooperation will eventually turn into formal joint exploration remains to be seen. For now, the Soviets are the ones to watch in the 1990s. ☐

Donald F. Robertson, a freelance writer from San Francisco, writes frequently for ASTRONOMY about space missions. His reports on the Soviet Phobos *mission and the U.S.* Mars Observer *mission appeared in the November 1987 issue.*

The Light-Hearted Astronomer
A Survival Manual for Amateur Astronomers



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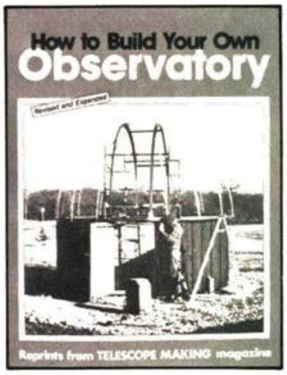
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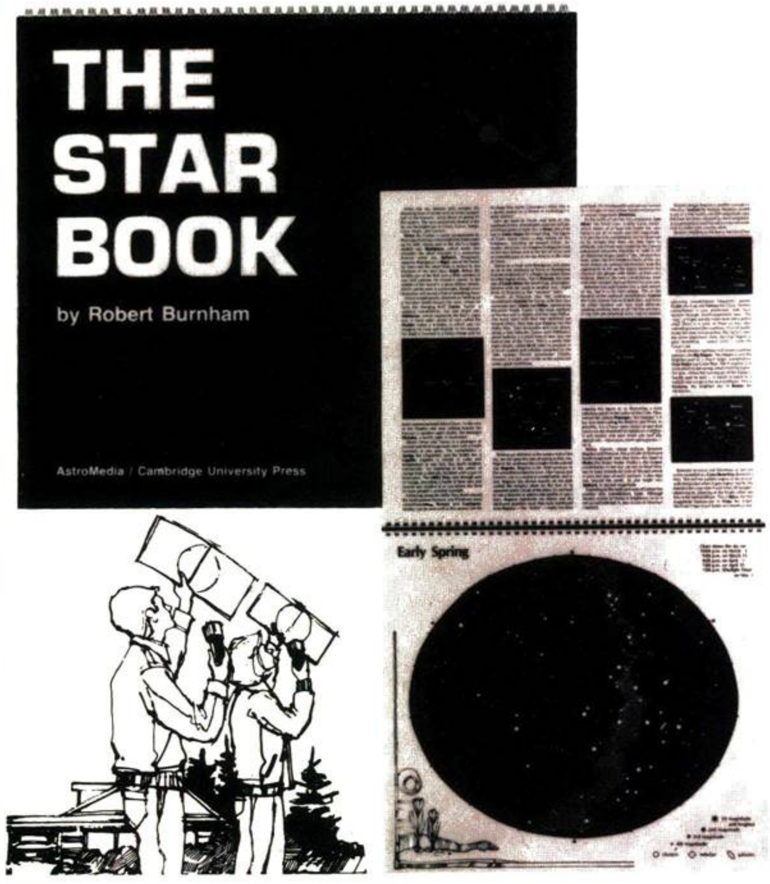

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The Telescope That Defies Gravity

Opticians, engineers, and computer programmers have designed the Keck telescope's thirty-six mirrors to function as one.

by Richard Berry

Gravity is the enemy of big telescopes. The giant precision mirrors astronomers use to collect light from the far reaches of the universe sag out of shape under the relentless drag of their own weight.

But astronomers and engineers building the 10-meter mirror for the Keck telescope have devised a way to beat the forces of nature. The stiffness that could not be achieved by the rigidity of glass and steel will be attained by actively controlling the mirror.

The giant primary mirror of the Keck telescope will consist of thirty-six hexagonal segments. As the array of mirrors sags and bends, small, computer-controlled motors will restore the segments to better than a millionth of an inch of their proper positions.

Size and Precision

Giant mirrors have supported astronomical research in the twentieth century. Astronomers have turned to giant mirrors to collect more light because more light means seeing farther into the depths of the universe.

The University of California (UC) and the California Institute of Technology (Caltech) are now equal partners in the California Association for Research in Astronomy (CARA). CARA is building the massive new telescope atop Mauna Kea in Hawaii, 13,600 feet above sea level, at one of the finest astronomical sites in the world. It is scheduled for first light in early 1990, and the total cost at completion will be $87 million.

Astronomers at UC and Caltech began thinking seriously about new telescopes more than a decade ago. The astronomers considered small telescopes, but they soon realized that a small telescope could not do the kinds of astronomy they wanted to do.

"I was asked to serve on a committee to evaluate the future of astronomy at the University of California," said project scientist Jerry Nelson. "The committee addressed questions such as what the future was and what equipment we ought to be thinking about or possibly building another telescope, size unknown.

"A couple of us on that committee were interested in very large telescopes. So we went off and thought about ways one might build very big telescopes, and we came back with the suggestion that a 10-meter telescope was technically and financially feasible and that it ought to have a segmented primary mirror."

With the donation in 1985 of $70 million from the W. M. Keck Foundation — the largest single gift ever given to a scientific project — the 10-meter telescope became a reality.

NOW TAKING SHAPE on the 13,600-foot-high summit of the Mauna Kea volcano in Hawaii, the dome for the Keck scope will house the world's largest telescope by 1990.

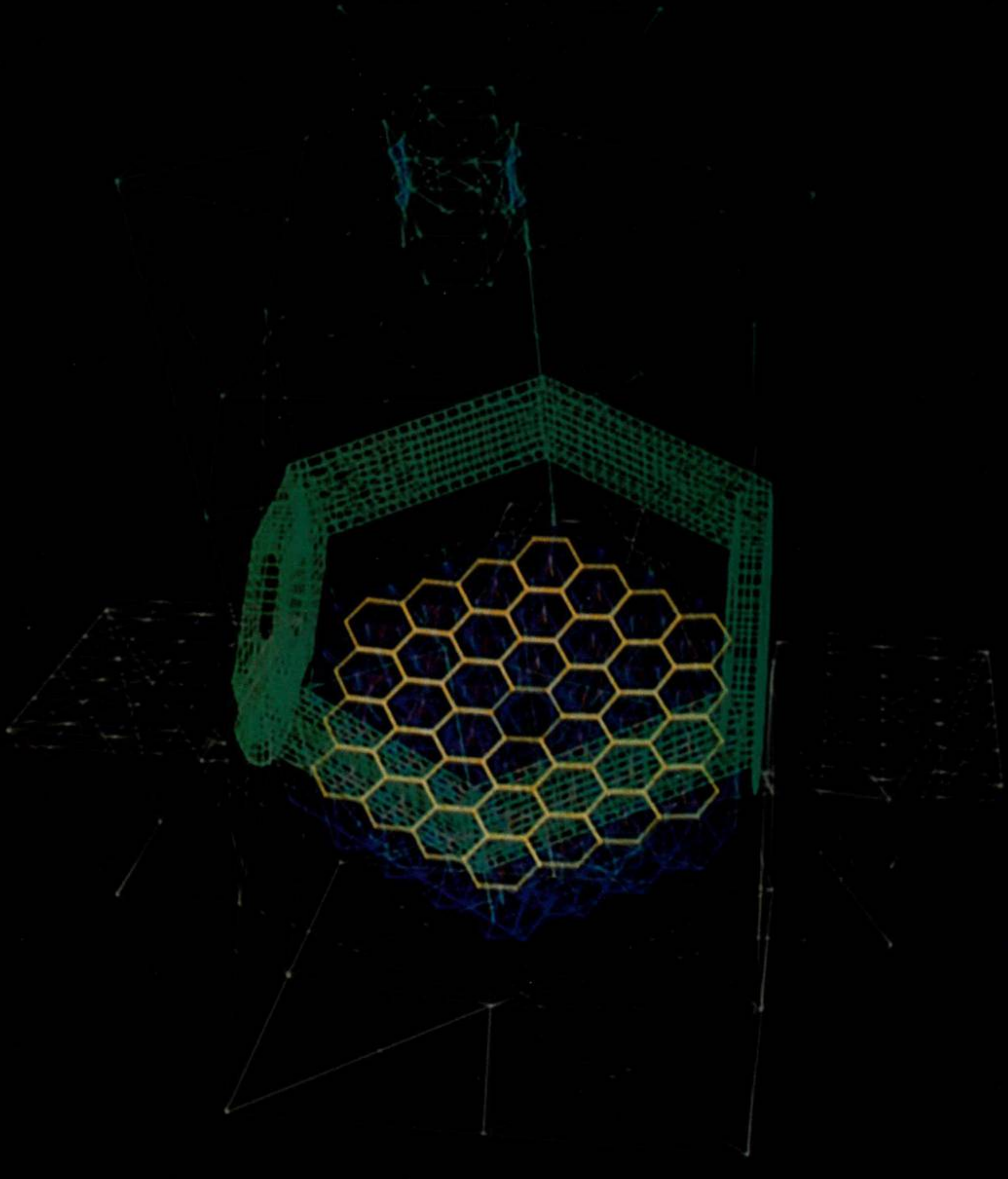
"We *need* the exceptional light-gathering capacity the Keck telescope will offer," said Sandra Faber, UC Santa Cruz and Lick Observatory astronomer and co-chair of the Keck's science steering committee. "That comes first and foremost."

"With the light-gathering power of a Keck, you can either do what you were doing before and take a quarter of the time to do it," said Wallace Sargent of Caltech and co-chair of the science steering committee, "or you can work on a much bigger project."

Both approaches are necessary. Research of great scientific merit may not get done simply because it would consume too much telescope time; the Keck will make that research go faster. Other projects couldn't be done at all; the Keck will make them possible.

"Lots of people have tried to study galaxy evolution just from counts and surveys — essentially pictures and brightnesses — but they have found that in the absence of redshift information it's all a big jumble," said Faber. "From a picture you just *don't know* whether a given galaxy is close and relatively faint or much farther away and gigantic. We need spectra to measure redshifts and get distances. That's where the 10-meter telescope will excel."

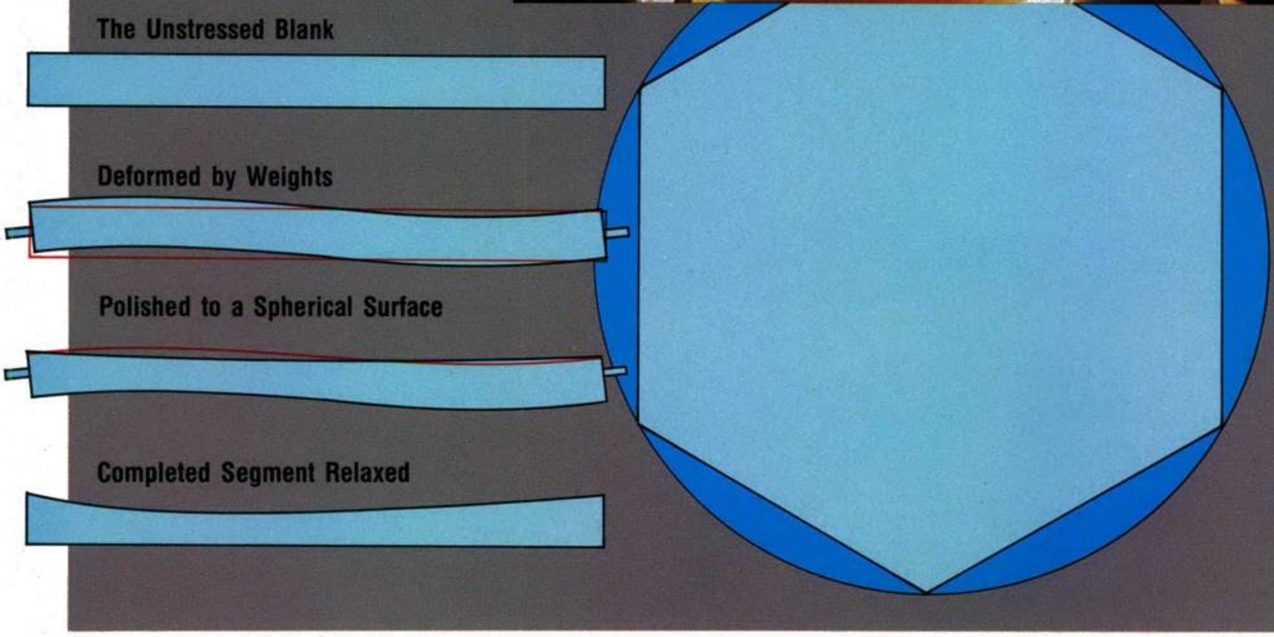
In addition to light-gathering power, the astronomers wanted the 10-meter telescope to provide the smallest



SEGMENTED-MIRROR TECHNOLOGY makes the Keck's spidery framework possible. The thirty-six-segment mirror (in yellow) is thinner and lighter than a single large mirror could ever be.

Making the Segments

PRECISELY SHAPED GLASS SEGMENTS are the heart of the Keck telescope. Raw glass (right) is cut into slabs, ground and polished (below), and trimmed into hexagonal segments.



possible images, both for taking pictures and for spectroscopy of very faint objects. "The smaller the images, the better," said Faber. The astronomers set stiff requirements for image quality: the errors in the telescope mirror could not significantly degrade the very best seeing, and 80 percent of the light from the huge mirror would fall within a 1/3-arcsecond circle.

For imaging and spectroscopy the goal was the largest possible field of view. "With the Keck," Sargent said, "the field will be 25 arcminutes. That's pretty good—it's about the size of a supercluster at a redshift of 2." A large field of view will enable the telescope to survey more sky faster.

A decade ago this meant fast photography of large sky areas. Recently, however, multiobject spectroscopy has created the need for large fields. Taking spectra used to mean that the telescope "looked" at only one object for many hours. But with fiber "light pipes," hair-thin strands of glass that carry light, spectroscopy has changed.

"When we put a fiber-fed spectrograph on the 10-meter," Faber said, "we'll be able to take spectra not of a single galaxy but of a hundred at a time. The Keck has six to ten times the light-gathering power of today's biggest telescopes. The net result is that on the Keck we'll be taking data a *thousand times* faster than we are now. That's enough to totally revolutionize the field."

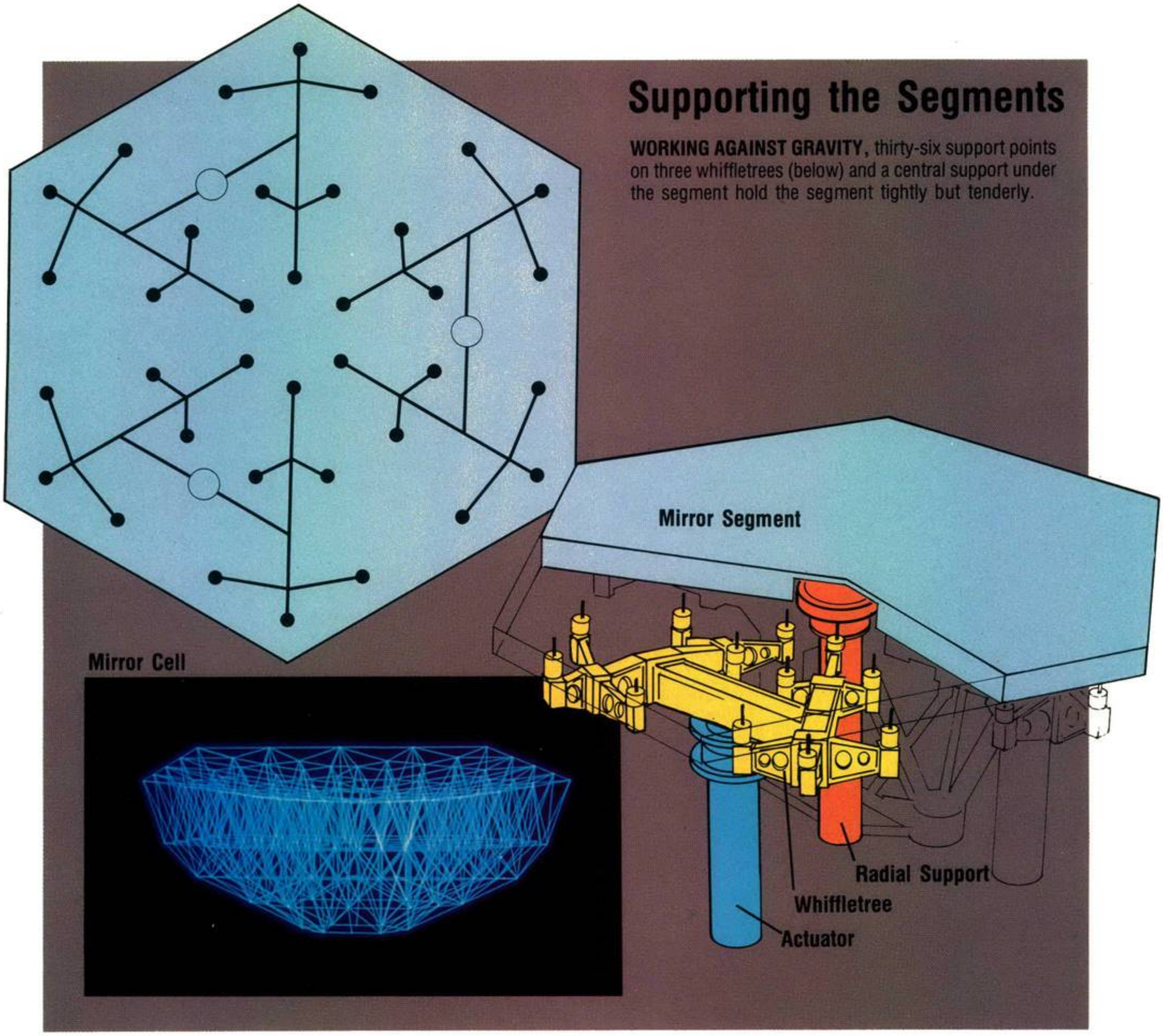
Telescope Design Alternatives

All existing large telescopes have had a single large mirror made from a single thick piece of glass, a so-called "monolithic" primary. Making the glass thick also stiffens the mirror so it can resist the pull of gravity.

As mirror sizes get larger, the monolithic approach breaks down. Because the mass of the mirror grows more rapidly than the mirror's ability to resist flexure, the larger a mirror gets, the more flexible it becomes. The 200-inch (5-meter) mirror in the Hale telescope is a very flexible mirror, but even its elaborate mechanical supports can barely keep the vast glass disk under control.

"Our fundamental optical concern with a large mirror remains the mirror's deformation under gravity," explained Nelson. "A 10-meter mirror is sixteen times more flexible than a 5-meter mirror, given the same mirror thickness and form of support.

"Besides," he added, "I wanted to spend my time



Supporting the Segments

WORKING AGAINST GRAVITY, thirty-six support points on three whiffletrees (below) and a central support under the segment hold the segment tightly but tenderly.

working on designs with a long-term future rather than on a design that is really close-ended. It's clear that there are limits to how large one can make a monolithic mirror. We can argue whether the limit is 5 meters or 6 meters or 8 meters, but it's obvious that the technological difficulty grows rapidly with size."

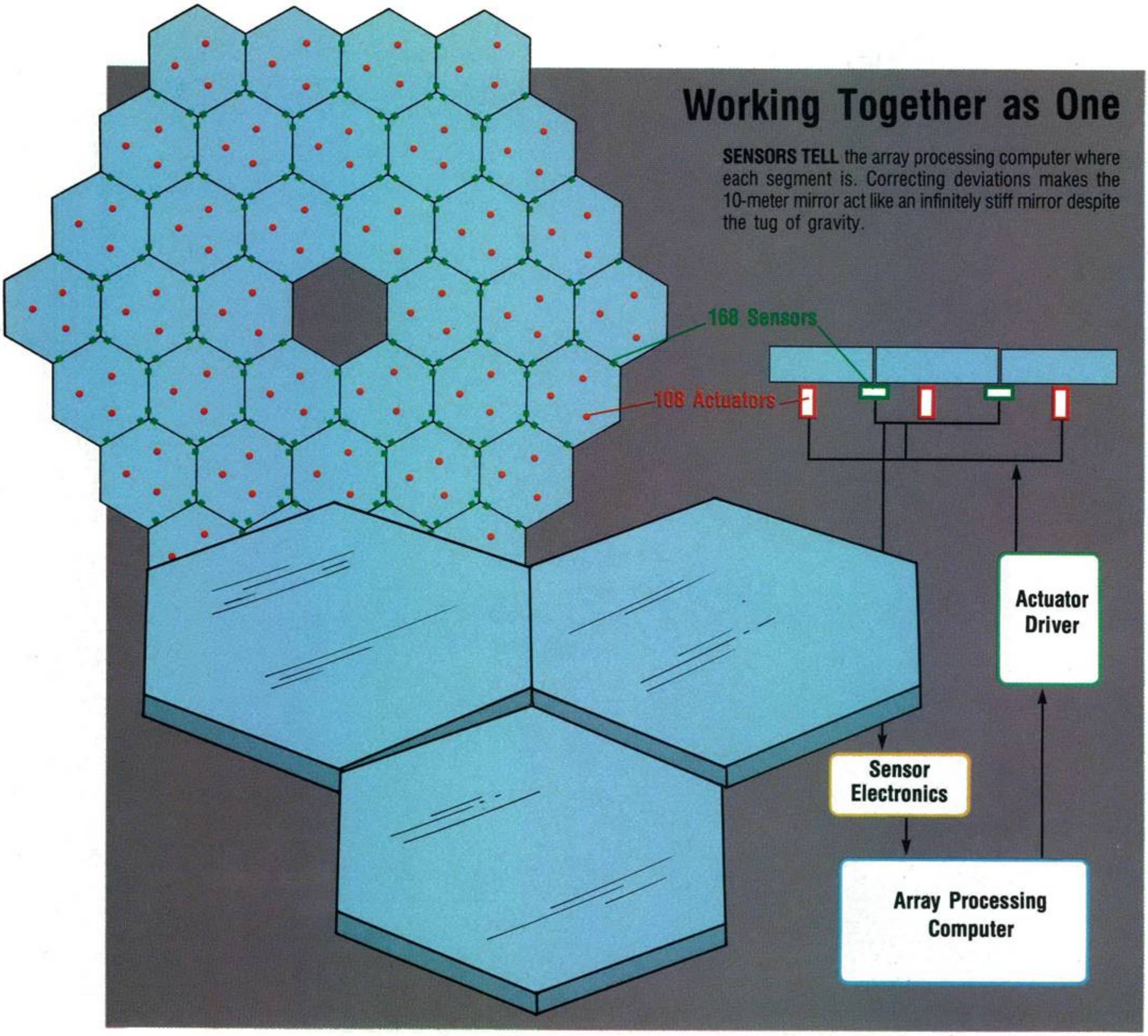
In 1978 a new type of telescope saw light: the Multiple Mirror Telescope, or MMT. The six 1.8-meter mirrors together have the light-gathering power of a single 4.4-meter telescope. Although the MMT has been an outstanding success and an effective telescope for some types of astronomical research, the UC and Caltech astronomers doubted that a 10-meter MMT could meet their performance criteria. "The difficulty of phasing the mirrors for diffraction-limited performance," said Faber, "and the difficulty of obtaining a large field of view led us to reject the MMT option."

That left Jerry Nelson's approach: segmenting the mirror. Because they are small, individual segments can be thin, and because they're thin, they're light. The segments in the Keck telescope are 75 millimeters thick — so all the glass for the Keck mirror will weigh a bit over 14 tons. That's what the 200-inch Hale telescope primary weighs — for a mirror with four times the area.

"Another virtue of small mirror segments is that we've kept the support system behind the segments relatively simple," said Nelson, "and the handling facilities are modest compared to the equipment you would need to horse a 10-meter mirror around."

Handling was something the astronomers wanted to avoid. As Nelson explained, "A monolithic mirror 10 meters across has to be thin, and being thin, it'll be fragile. The consequence of breaking that mirror is really hideous. With segments we don't worry. If we break a segment, we put in a replacement. We're making a spare for each of our six segment types."

Astronomers like the segmented mirror approach. "We have a bigger telescope as a result of segmented mirror technology," said Faber. "That's its most important benefit. We went from talking maybe 7 or 8 meters for a telescope with a monolithic mirror to talking 10 meters with a segmented mirror. What more can I say? I'm *very* enthusiastic about the 10-meter telescope. It's a very ambitious project, but it's not impossible."



Working Together as One

SENSORS TELL the array processing computer where each segment is. Correcting deviations makes the 10-meter mirror act like an infinitely stiff mirror despite the tug of gravity.

Making Segments

The mirror of the Keck telescope will be 10 meters across — that's 32 feet and 10 inches — with a gentle bowl-shape about 35 centimeters (just over a foot) deep. Its focal length is 17.5 meters; its form, a hyperboloid.

If the mirror were a giant sphere, it would be hard enough to make. The job would then be to make thirty-six identical hexagonal mirrors, because every segment of a sphere is itself spherical.

Said Fred Vescelus, CARA's assistant project manager for the Keck telescope, "The segments are hard to make because they have to match. The first mirror you get almost free, but then the subsequent segments have to match that radius to 1 part in 100,000. That's kind of a toughie."

Because the mirror must be hyperboloidal to give the astronomers a wide field of view at the focus, the segments are off-axis pieces of a hyperboloid — neither spherical nor rotationally symmetric. One side of each segment is more steeply curved than the other, and there must be six different kinds of segment.

The aim of stressed mirror polishing is reducing the complex problem of polishing an aspheric surface to that of polishing a sphere. It's done by applying force to the mirror blank in such a way that the blank is temporarily deformed. A spherical surface is then polished into it. After polishing, the forces are removed. The glass returns to its unstrained shape, and the spherical surface twists into the surface of the segment desired.

Each mirror blank is placed in a special jig. Around the mirror's rim the opticians cement twenty-four horizontal levers and hang carefully calculated lead weights from them. The weights deform the blank, the opticians grind and polish a spherical surface into the glass, and the mirror is taken out of the jig.

"Once we're through with stressed mirror polishing and we've cut the blank into a hexagonal segment," said Nelson, "we attach a support system to the blank — the same support system the segment will have in the telescope — and then test it on that support system." At this point the mirror surface should be nearly perfect. "The final stages of polishing, the last 100 nanometers or so, are done on a computer-controlled polishing machine with the segment on its supports."

Supporting the Mirror

While segmenting the primary solves one set of problems, it creates a new set of problems: how to hold thirty-six precisely shaped mirror segments in perfect alignment. Fourteen tons of glass must be suspended with the precision of a tenth of a wave of light — in all positions, at all temperatures, at all times.

No single remedy could solve the support problem. Instead, the designers split the task between two subsystems. There's a passive system of supports under each segment that "floats" the segment free of gravity so it does not deform under its own weight. There's also an active system: sensors bridge the gaps between the segments and measure the movement of each segment relative to the others. Actuators, driven by computer-controlled motors, raise and lower the segments back into place when the sensors detect relative motion. The active system can move each segment by as little as 4 nanometers, less than a millionth of an inch.

The mirror cell supports both the active and the passive systems and is part of the passive system itself in some respects. The cell is a massive structure of welded steel more than 10 meters across. If it were possible to make the cell sufficiently stiff, then the active control system for the segments would not be needed. Although it has been designed to be as stiff as possible, however, the cell, supporting 14 tons of glass, 6 tons of instruments, and 5 tons of its own weight, flexes nearly a millimeter — some 20,000 times the allowable deviation in the mirror.

The cell holds thirty-six subcells, one subcell for each segment. The subcells hold the components of both the passive and the active support systems — whiffletrees, radial supports, and actuators.

Each subcell holds three actuators, each actuator holds one complete whiffletree, and each whiffletree holds the segment at twelve points. Thus each segment is axially supported at thirty-six points on three actuators and supported against sideways forces by one radial support. There are 108 actuators in total.

"The whiffletrees provide support when the telescope is looking at the zenith," explained Fred Vescelus, "so the entire weight is distributed over the whiffletree structure. When the telescope is pointed at the horizon, the load is taken by the radial supports. The radial supports and the whiffletrees take out the load in different directions."

Test whiffletrees have worked extraordinarily well. Without support, a segment will bend 1,700 nanometers out of shape (about seventy millionths of an inch). With whiffletree support, that's reduced to 8 nanometers.

"Inplane forces," said Nelson, "are carried through the radial support system. It's a thin diaphragm built into the center of the mirror." The stainless steel diaphragm is the thickness of a file card, so it flexes freely as the actuators move the mirror up and down, but, like a taut drumhead, it won't allow sideways motion.

The whiffletrees have just the opposite characteristic. They're attached to the glass through spaghetti-thin metal rods. The rods can't transfer sideways forces to the mirror because they simply bend, but endways they support the weight of the segment. Working hand in hand, the radial supports and whiffletrees allow the segment to "forget" about gravity.

Controlling the Mirror

As the Keck telescope moves to different celestial objects, the mirror cell will flex and the mirror segments will shift relative to one another. A total of 168 sensors, two on each shared side of the hexagonal mirror segments, will sense motions as small as 1 nanometer. The sensors are attached to the back sides of the segments and do not block any light.

Each sensor consists of a "body" attached to one segment and a "paddle" attached to the segment beside it. The paddle crosses the gap between the mirrors and extends into the body, its top and bottom sides not quite touching the surrounding body. Thin gold coatings on the top and bottom sides of the paddle and the body act as electrical capacitors; an electronic circuit compares them and senses the precise position of the paddle.

The outputs of all 168 sensors feed into nine dedicated microprocessors. "In theory," Vescelus said, "you pick one mirror that's in the middle of its range of control and you say, this mirror is in the right position. The matrix algorithm in the computer solves the question of where the other mirrors should be relative to this mirror." Twice each second the control system sends a command to each of the 108 actuators.

Each actuator contains a small, digitally controlled motor that turns a precision screw; as the motor turns the screw, the actuator pushes or pulls the whiffletree it supports forward or backward. Because there are three actuators per segment, the actuators, working in unison, can tip the segment in any direction as well as moving it by as little as 4 nanometers.

A Revolution in the Making

"The gain we expect in doing surveys of galaxy redshifts is huge," said Faber. "The Keck telescope will gain a factor of four in light-gathering power over the 200-inch for the aperture of the telescope, but the real gain is probably more like six or seven times because the speed of a telescope on faint objects depends critically on the atmospheric image quality, and the seeing on Mauna Kea is superb.

"The Keck and the Space Telescope are almost exclusively complementary in what they do well," said Faber, "so they'll work together. You don't study star formation with one telescope and galaxy evolution with another telescope. Instead, you need different kinds of data, and you need to take that data with different kinds of telescopes."

What was the universe like 10 billion years ago? With its immense light-gathering power, the Keck telescope and its powerful spectrographs and cameras will dissect the light from galaxies and quasars on the fringes of the observable universe. It will probe the origins of stars, of galaxies, and of the universe itself.

"Like buried treasures, the outposts of the universe have beckoned to the adventurous from immemorial times," wrote George Ellery Hale in 1927, as he began the effort that culminated in the 5-meter telescope on Palomar Mountain. "Princes and potentates, political or industrial, have felt the lure of the uncharted seas of space, and through their provision of instrumental means the sphere of exploration has widened. If the cost of gathering celestial treasure exceeds that of searching for the buried chest of a Morgan or a Flint, the expectation of rich return is surely greater and the route not less attractive."

Hale's observation is once again borne out. The ineffable lure that beguiled Lick, Yerkes, and Hooker has once again worked its magic with the Keck Foundation — and once again, a giant telescope is making ready to explore the depths of space. ☐

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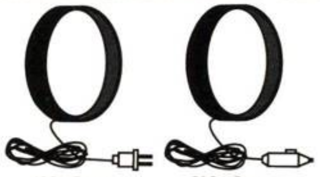
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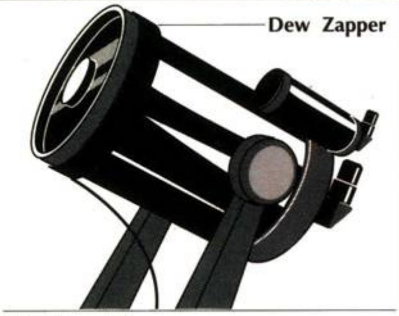

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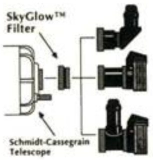

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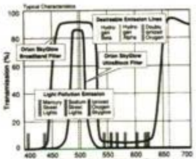

The combination of high transmission of desireable bands and extremely low transmission of pollution bands results in the highest contrast gain of any competing light pollution filter you can buy.

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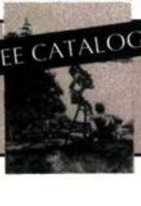

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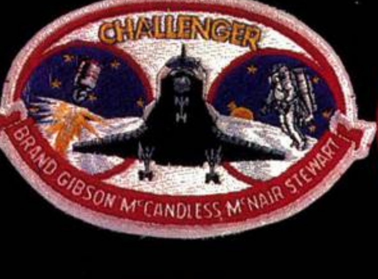
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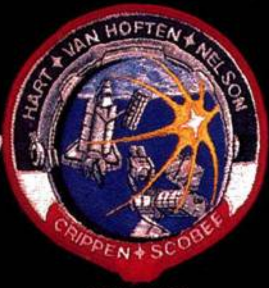
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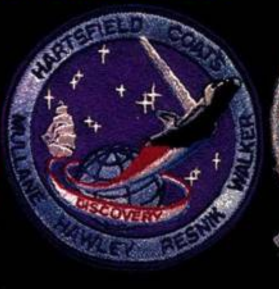
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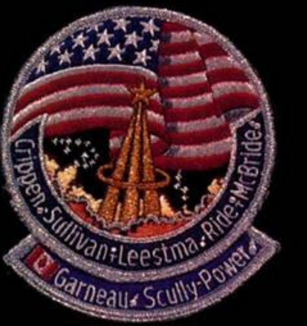
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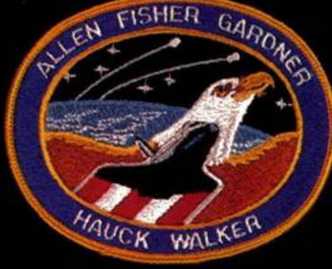
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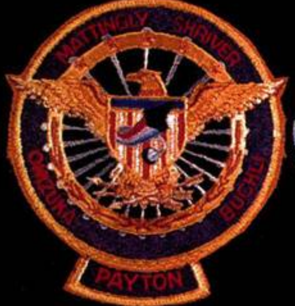
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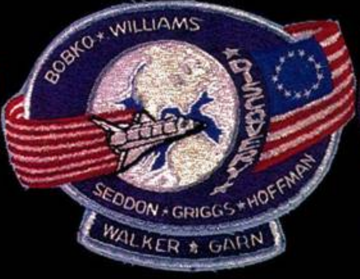
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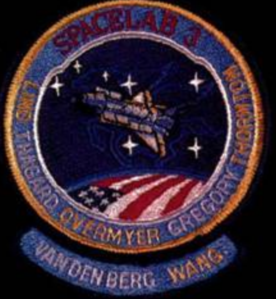
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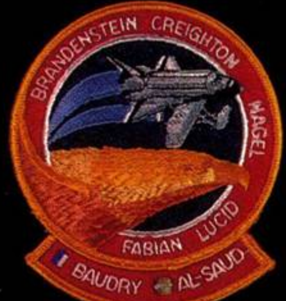
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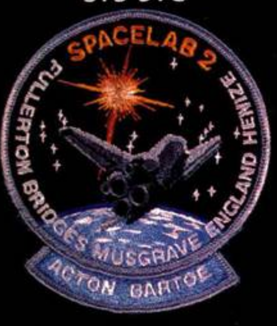
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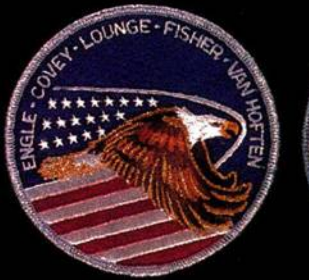
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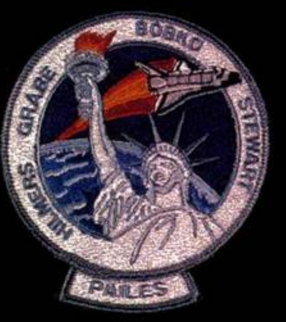
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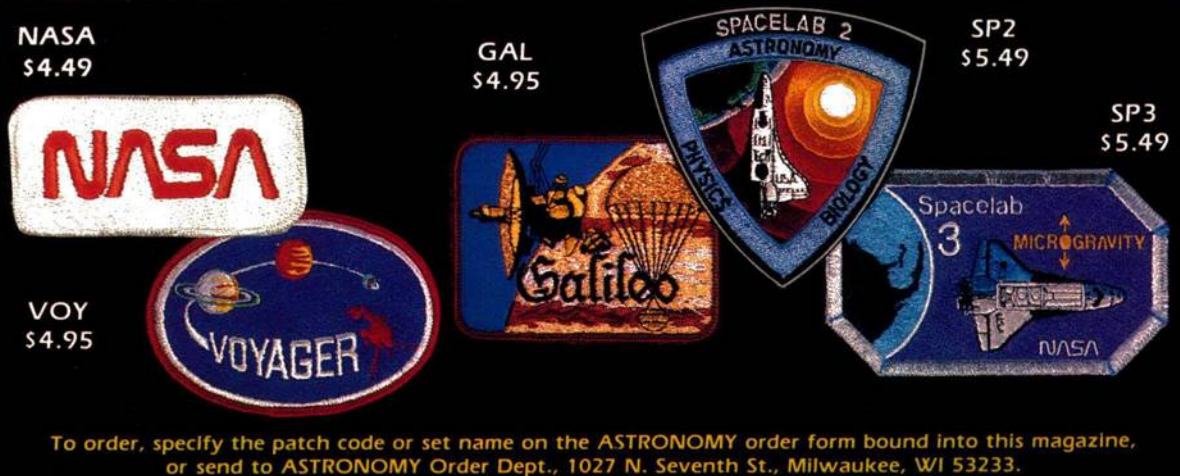
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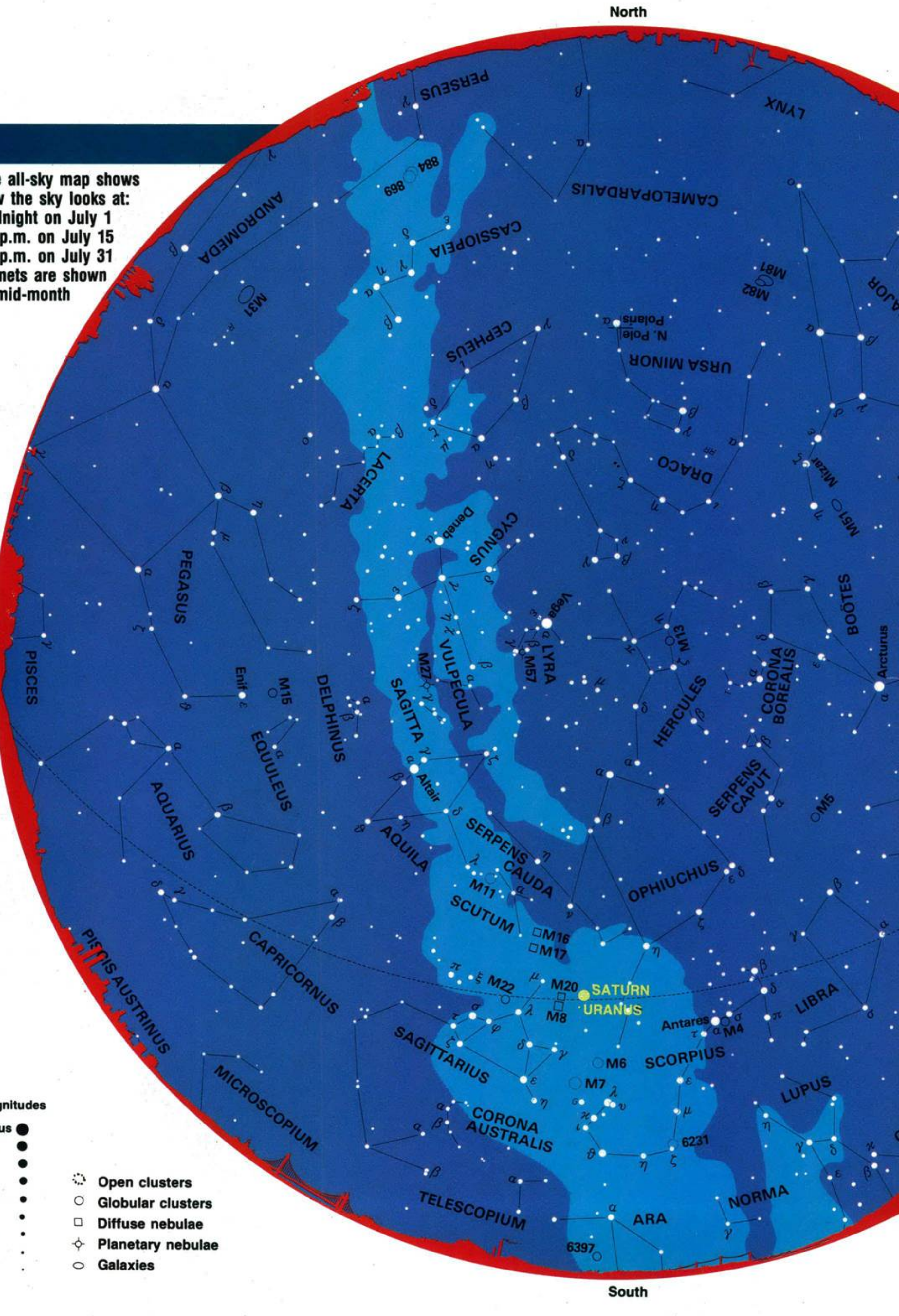
The all-sky map shows how the sky looks at:
Midnight on July 1
11 p.m. on July 15
10 p.m. on July 31
Planets are shown at mid-month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884
M31
M81
M82
CEPHEUS
N. Pole
Polaris
URSA MINOR
LACERTA
DRACO
Mizar
M51
Deneb
CYGNUS
PEGASUS
BOÖTES
Vega
LYRA
M57
M13
PISCES
Enif
M15
DELPHINUS
M27
VULPECULA
SAGITTA
HERCULES
CORONA BOREALIS
Arcturus
EQUULEUS
Altair
SERPENS CAPUT
M5
AQUARIUS
AQUILA
SERPENS CAUDA
OPHIUCHUS
M11
SCUTUM
M16
M17
CAPRICORNUS
PISCIS AUSTRINUS
M22
M20
M8
SATURN
URANUS
Antares
M4
LIBRA
SAGITTARIUS
M6
SCORPIUS
M7
MICROSCOPIUM
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
NORMA
6397

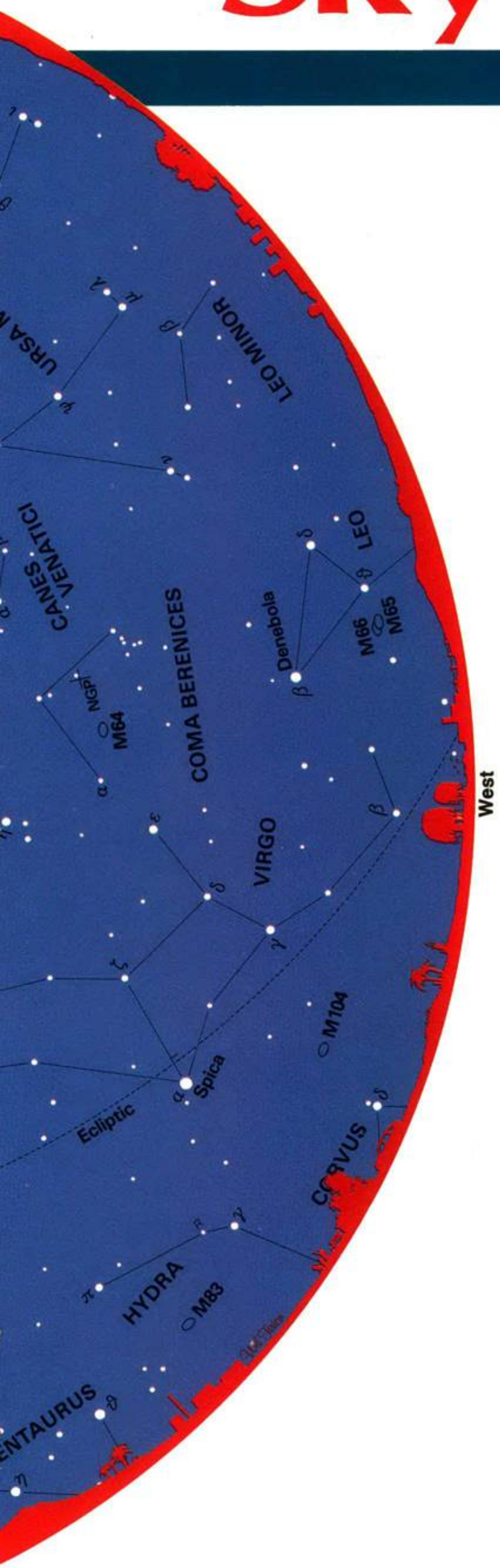
Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 •
2.4 •
3.2 •
4.0 •
4.8 ·
5.6 ·

- ⁘ Open clusters
- ○ Globular clusters
- □ Diffuse nebulae
- ⌖ Planetary nebulae
- ⬭ Galaxies

Sky Almanac

JULY 1988



Map Art by Wil Tirion

VENUS PROMINENT IN MORNING SKY

Venus dominates the predawn sky this month, rising earlier and climbing higher each day as it moves away from the Sun. The planet reaches greatest brilliancy on July 19.

MOON COVERS REGULUS ON JULY 16

The slim crescent Moon passes in front of the bright star Regulus during the early evening hours of July 16. Observers throughout North America can see at least part of the event; the best view is from the middle of the continent.

MARS DOUBLES IN BRIGHTNESS

The Red Planet grows rapidly in brightness and apparent size during July. Prominent from midnight to sunrise, Mars is moving toward opposition on September 27.

COMET TEMPEL 2 COMES INTO VIEW

Periodic comet Tempel 2 should become bright enough to view in 6- to 8-inch telescopes this month; however, predictions of its magnitude vary considerably.

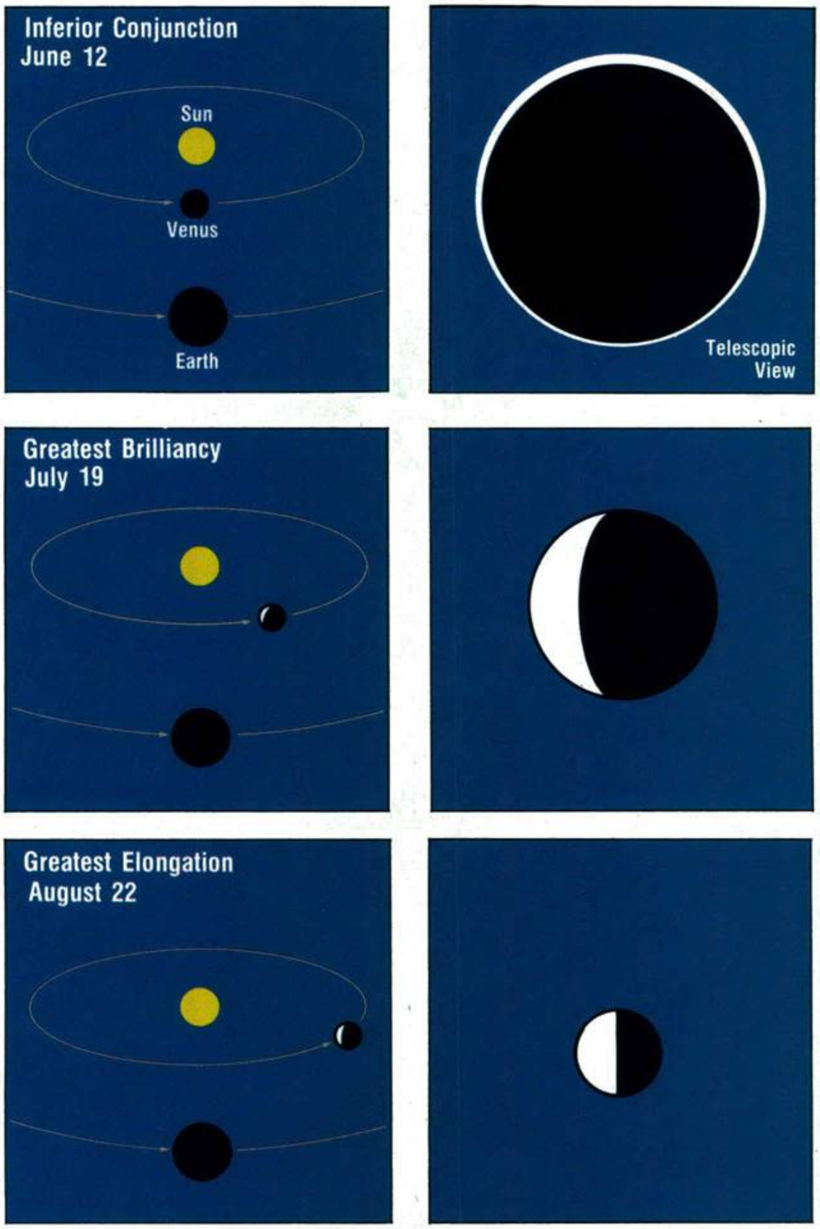
JUPITER NEAR THE PLEIADES

Jupiter passes 5° south of the Pleiades star cluster this month. Venus joins the two objects early in the month as it heads toward greatest brilliancy.

Dates and Times

2 Moon at perigee (225,972 miles from Earth)
4 Venus stationary
5 Earth at aphelion (94,509,940 miles from Sun)
Mars 5° south of Moon
6 Last Quarter Moon, 7:36 a.m. EDT
Mercury at greatest western elongation (21°)
13 New Moon, 5:53 p.m. EDT
16 Regulus occulted by Moon, 10 p.m. EDT
17 Moon at apogee (251,975 miles from Earth)
19 Venus at greatest brilliancy (−4.5 magnitude)
21 First Quarter Moon, 10:14 p.m. EDT
25 Antares 0.6° north of Moon, 1 a.m. EDT
Pluto stationary
28 Full Moon, 11:25 p.m. EDT
30 Moon at perigee (223,278 miles from Earth)

Eye on the Sky by Deborah Byrd



VENUS APPEARS BRIGHTEST when it is close enough to Earth to present a large disk but far enough ahead in its orbit that we see a substantial crescent.

VENUS AT GREATEST BRILLIANCY

The planet Venus is a glittering beacon in the morning sky this month. It shines in the east before dawn, climbing higher as the month progresses, and reaches greatest brilliancy on July 19.

Greatest brilliancy for Venus happens only once in every ten-month apparition when Venus is relatively near Earth in its smaller orbit around the Sun. The date of greatest brilliancy depends on the tradeoff between Venus' nearness — and thus the apparent size of Venus' disk — and the thickness of Venus' visible crescent.

On July 19, Venus is only slightly more than 40 million miles from Earth. Although this distance is 50 percent larger than it was last month when the planet passed between the Sun and Earth, Venus will be 100 million miles farther away by the end of 1988. The planet's disk, visible through a small telescope, is much larger now than it will be at the end of the year.

Although it is large, the disk of Venus does not appear fully lit now. Through a telescope this inner world looks like a tiny crescent Moon: its lighted hemisphere faces mostly away from our direction. The crescent Venus appears brighter than a more fully lit Venus simply because Venus is still nearby and its disk is relatively large.

THE RED PLANET BRIGHTENS

Mars doubles in brightness in July. Rising around midnight, the Red Planet is rapidly approaching one of its best apparitions in this century. In each of the past few months Mars has brightened by slightly more than one-and-a-half times. This month Mars brightens by a factor of two, going from magnitude −0.8 in early July to −1.5 at month's end.

Earth is now hot on the heels of Mars in the race of the planets around the Sun. We will pass between Mars and the Sun in late September when the Red Planet will be closer and brighter than at any time since 1971.

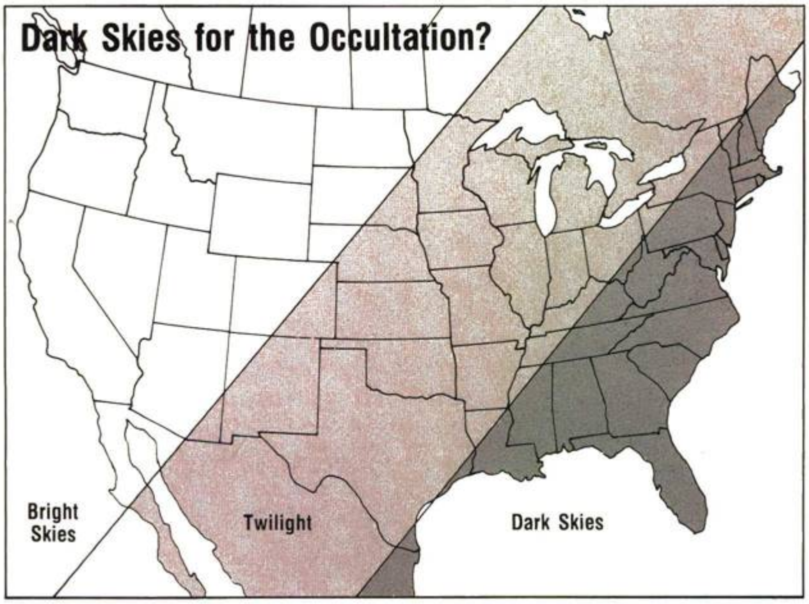
REGULUS HIDDEN BY THE MOON

The bright star Regulus is covered by the crescent Moon on the evening of July 16. The Moon appears as a slim crescent, only 9 percent illuminated, low in the western sky after sunset. Pick out the Moon as early as you can in the evening. First-magnitude Regulus disappears behind the Moon's dark limb for people throughout North America and the Arctic. In the United States the occultation is best seen from the central part of the country. (In the East the Moon sets before the occultation is complete, while in the West the Sun sets at about the time the event begins.) The occultation should be visible to the naked eye, although binoculars will enhance the view.

JUPITER PASSES THE PLEIADES

The king of planets, prominent in the east before dawn, passes just 5° away from a tiny dipper-shaped cluster of stars this month. The Pleiades, or Seven Sisters, form one of the brightest star clusters in the sky. The cluster looks so much like a tiny dipper that some people mistake it for the real Little Dipper (Ursa Minor), which is located farther north.

Jupiter passes closest to the Pleiades in July, though the planet and the cluster remain within 10° of each other through the end of the year. The two will be separated by 5° once again in December.


Dark Skies for the Occultation?
Bright Skies
Twilight
Dark Skies

REGULUS DISAPPEARS in progressively darker skies the farther east you go (above). Both the path the Moon takes as it occults Regulus and the time the occultation occurs differ depending on your location (bottom).

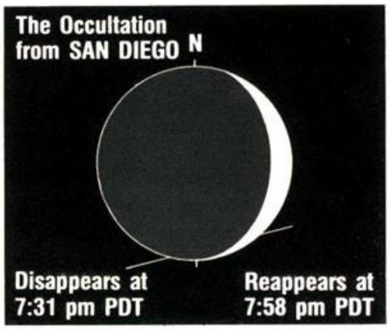
JULY'S PLANETS

Only one bright planet can be seen in the early evening sky this month. Saturn rises in the east as the Sun sets in the west and the planet makes a low arc across the southern sky throughout each night. It appears as a bright, steady beacon in the constellation Sagittarius, a rich region of the summer Milky Way. Notice the color contrast among soft golden Saturn, the white sweep of the Milky Way, and the deep orange glow of Antares in nearby Scorpius.

Saturn is now only one month past opposition, when it was directly opposite the Sun in Earth's sky. Planets at opposition are generally at their brightest, and Saturn was slightly brighter last month than it is now. At the end of July it shines at magnitude +0.2 and lies 850 million miles away.

In the middle of the night a procession of planets rises in the east, and each ascending planet is brighter than the last. Ruddy Mars appears first. It rises just after midnight when the month begins and in late evening by month's end. At sunrise Mars is high in the south.

Jupiter is in the constellation Taurus and comes up about two hours after Mars. It is well up in the southeast at sunrise and is currently brighter than Mars — but not for much longer. The Red Planet will surpass Jupiter in brightness this September.


The Occultation from SAN DIEGO
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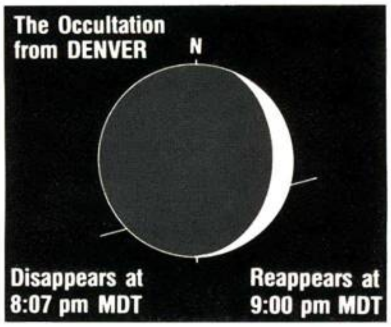
Disappears at 7:31 pm PDT
Reappears at 7:58 pm PDT


The Occultation from DENVER
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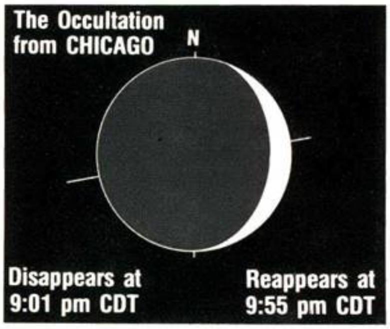
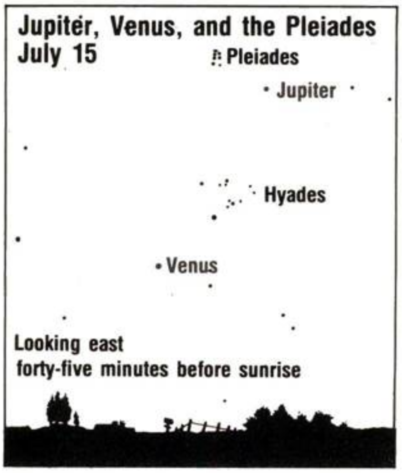
Reappears at 9:00 pm MDT


The Occultation from CHICAGO
N
Disappears at 9:01 pm CDT
Reappears at 9:55 pm CDT


Jupiter, Venus, and the Pleiades
July 15
Pleiades
Jupiter
Hyades
Venus
Looking east
forty-five minutes before sunrise

Jupiter will spend the remainder of 1988 in the vicinity of the Pleiades and another large star cluster, the V-shaped Hyades. Jupiter won't be making much headway against the stars over the next several months. Its retrograde (westward) motion will begin in September. We'll pass between Jupiter and the Sun in November, and the giant planet won't start moving eastward again until early

1989. That's the scientific reason for Jupiter lingering near these two star clusters for so long.

Before daybreak another planet rises over the eastern horizon. Venus, the brightest of them all, comes up shortly before the beginning of morning twilight early in the month. By month's end it rises a couple hours before dawn and stands well up in the predawn sky. Venus is always unmistakable because of its dazzling brightness. On July 19, it reaches greatest brilliancy and it shines at magnitude −4.5.

Just before dawn in early July you might glimpse Mercury. It rises shortly before the Sun does and is located below Venus in the eastern sky. Greatest elongation is on July 6, when Mercury is 21° from the Sun. Unfortunately Mercury does not easily come into view during this apparition and plunges into the Sun's glare by mid-July. A better morning apparition of Mercury will take place in October.

JULY'S STARRY SKY

Looking south on a warm July evening, you will see two bright objects dominating the sky. To the east is golden-colored Saturn, the most distant of the naked-eye planets. To the west is the star Antares, half as bright as Saturn but nonetheless the brightest star in this region of sky.

Saturn lies in the constellation of Sagittarius the Archer to the northwest of the asterism known as the Teapot. The center of our Galaxy lies in the direction of Sagittarius, and the section of the summer Milky Way that passes through this constellation is excellent for binocular exploring. West of Sagittarius — and due south on July evenings — is the distinctive constellation Scorpius the Scorpion.

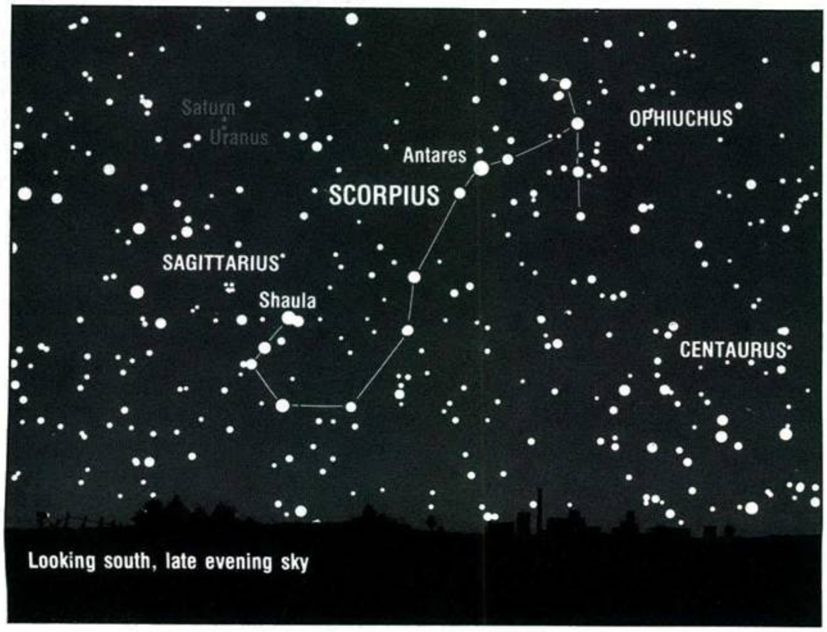
Golden orange Antares twinkles at the heart of the Scorpion, and most of the rest of the constellation curves down toward the southern horizon, looking very much like a scorpion's tail.

The name Antares means "rival of Ares," or "rival of Mars." This year, however, there's no contest between the two: Mars is already much brighter. On the evening of July 24, the waxing gibbous Moon passes just south of Antares, occulting the star for observers in eastern Australia, New Zealand, southern South America, and Antarctica.

Located above the Scorpion's ruby heart are three stars that form a tiny arc. These three are sometimes called "the crown of the scorpion" and represent the head of Scorpius.

At the other end of Scorpius is the Scorpion's tail, located in a rich region of the summer Milky Way and a fine area for sweeping with binoculars. The brightest star in the tail is called Shaula, which means "the sting."

Scorpius is easiest to see from southerly latitudes and shows best from the Southern Hemisphere. In a legend that comes from New Zealand, this constellation was considered a magic fishhook, given to a young fisherman by a goddess of the underworld. When he pulled this fishhook up from beneath the waves, the fisherman found that he'd caught an entire island complete with houses and people! According to this legend, this is how the island of New Zealand was formed. Afterwards the young man threw the fishhook into the sky, where we see it today as the constellation Scorpius.



Looking south, late evening sky

Through the Eyepiece by Rick Shaffer

VENUS' BRIGHTENING CRESCENT

Venus has just begun its steady march through the morning sky, having reached inferior conjunction on June 12. Because it has just passed nearly between Earth and the Sun, Venus presents a large, only partly illuminated disk that resembles a very old Moon.

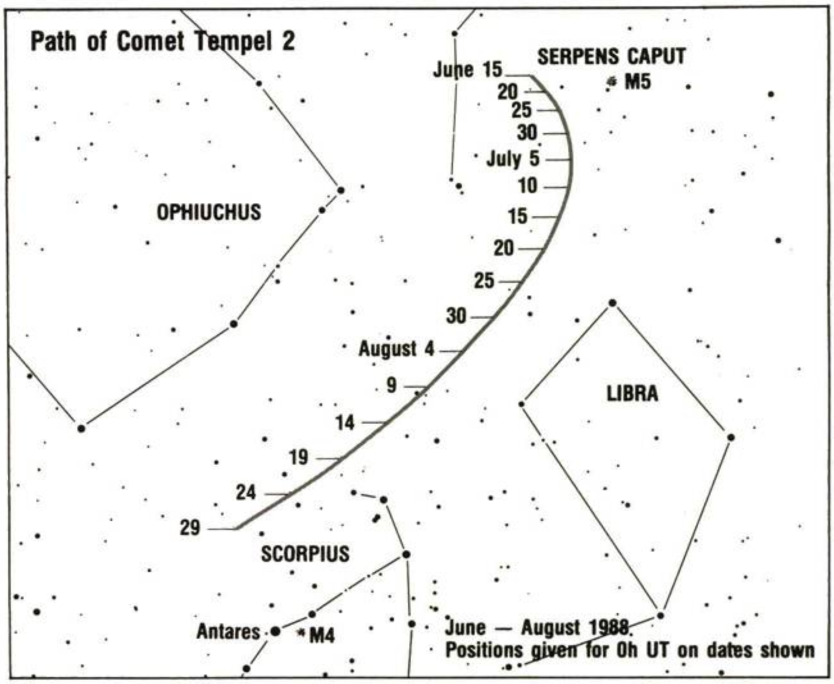
On July 1, Venus rises a little over an hour before the onset of astronomical twilight, so you won't have a lot of time to observe the planet. Look low on the horizon and due east to spot the bright planet. You'll find that if you start to observe Venus just as twilight begins, you will be able to follow the planet right through sunrise if you wish.

Venus' disk will be 49" in diameter on the 1st, and it shines at magnitude −4.3. By the 15th, Venus rises slightly more than one hour before twilight. Its disk is a bit smaller at 40", but it has brightened to magnitude −4.5. Though Venus reaches greatest brilliancy on July 19, it will be bright enough all month to spark the usual flurry of UFO reports. By the end of the month Venus rises about two hours before the beginning of twilight, shining at magnitude −4.4 with a disk 31" in apparent diameter.

Although the sheer beauty of the universe is reason enough to make astronomical observations, you can enhance your observing pleasure by making systematic records of what you see. A good way to get started is by observing Venus every week or so for the next few months. With as high a power as you can, make a drawing of the planet each time you observe it. Scale the drawing of Venus relative to the field diameter of your telescopic view, and use the same high magnification each time you make a drawing.

Your goal is to accurately draw the grossest feature of a very bright object — the phase of its disk — and for this you need to make this feature appear as big as possible. Don't expect to see any detail on either the sunlit or dark side of Venus. Note that using very high powers, regardless of the steadiness of the atmosphere, is not recommended for all planetary viewing. In most cases you're trying to view small, subtle planetary detail, for which an extremely high power is often inappropriate.

When you finish, you'll be able to place your drawings side by side and see both the changing phase and apparent size of Venus. Younger readers with access to a small telescope might find this a good elementary-school or junior-high science project. However, I believe it's a good project for beginners of all ages.


Path of Comet Tempel 2

June — August 1988. Positions given for 0h UT on dates shown

THE RETURN OF TEMPEL 2

July is the first month periodic comet Tempel 2 should be bright enough to observe with a moderate aperture. But there are large discrepancies in the predictions of just how bright Tempel 2 will be, so the comet could be anything from fairly easy to quite difficult to see.

Brian Marsden of the International Astronomical Union's Bureau for Astronomical Telegrams believes Tempel 2 will begin July at roughly 9th magnitude and brighten to 7th or 8th magnitude by August.

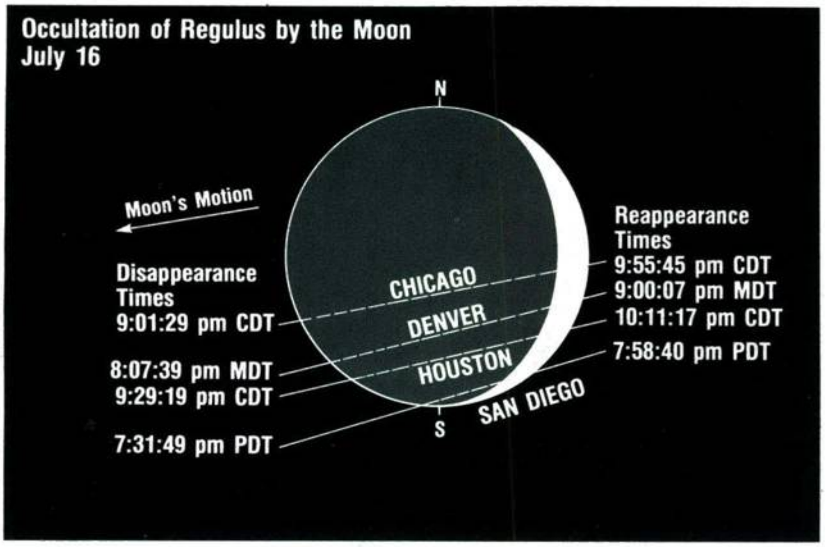
Indeed, the standard model used to predict comet brightnesses indicates that Tempel 2 will be quite bright. Charles Morris of the *International Comet Quarterly* believes Tempel 2 will be four or five magnitudes fainter than predictions based on the standard model, which would put it at 12th or 13th magnitude by month's end. Morris bases his prediction on the behavior of Tempel 2 during the comet's last three apparitions, when the comet was consistently fainter than the standard model predicted.

Tempel 2 offers you the unusual opportunity to see for yourself who made the closer call. Follow the comet as it tracks through Serpens Caput, Libra, Scorpius, and Ophiuchus during the next few months. By perihelion on September 16, we should know the answer.

TRAIN YOUR SCOPE ON MARS

Mars changes rapidly in size and brightness this month. The Red Planet's disk will grow 30 percent larger during July and its brightness will double. Although Mars will be biggest and brightest in September, there are several important reasons to start observing the planet now.

First, ferocious dust storms on the surface of Mars often coincide with favorable oppositions. The 1971 opposition exhibited an almost featureless disk for weeks on end because a nearly planetwide dust storm raged. If you observe Mars over a six-month period, you'll most likely protect yourself from Mars' weather dusting on your observing parade.


Occultation of Regulus by the Moon
July 16

Second, you'll train your eye to detect subtle details on the planet's disk, and this eye-brain training cannot happen overnight. To improve your ability to perceive fine detail and subtle differences in color and shading, you must put in a significant amount of time.

REGULUS BLINKS OUT

At approximately 2h UT on July 17 (the evening of July 16 in North America), the disk of the Moon passes in front of the 1st-magnitude star Regulus in Leo. The occultation is visible to most North American observers, although the Moon sets before the event is over for East Coast observers and will still be in bright twilight in the West. Binoculars or a telescope will improve your view as Regulus disappears behind the Moon's dark limb and reappears out of a 9 percent lit crescent.

JULY'S PLANETS

Except for Saturn, the evening sky this month is devoid of planets that show detail in backyard telescopes. At mid-month the equatorial diameter of Saturn's disk is only 18″, but Saturn's rings stretch 41″ across. The rings are tilted as wide as they can be this year, which should allow you to easily see Cassini's Division, a dark gap between the bright middle ring, or B-ring, and the dimmer outer ring, or A-ring.

Uranus lies just over 1° south of Saturn at the beginning of July and remains within 2° of the ringed planet during the month. If you haven't observed Uranus before, this is the month to capture the magnitude 5.6 planet. Don't expect your telescope to reveal any details beyond a pale green disk 3.8″ in apparent diameter.

Neptune, which reached opposition on the last day of June, is well placed for viewing in July. Moving westward against the stellar background of eastern Sagittarius, the magnitude 7.9, pale green planet subtends an angle of 2.3″.

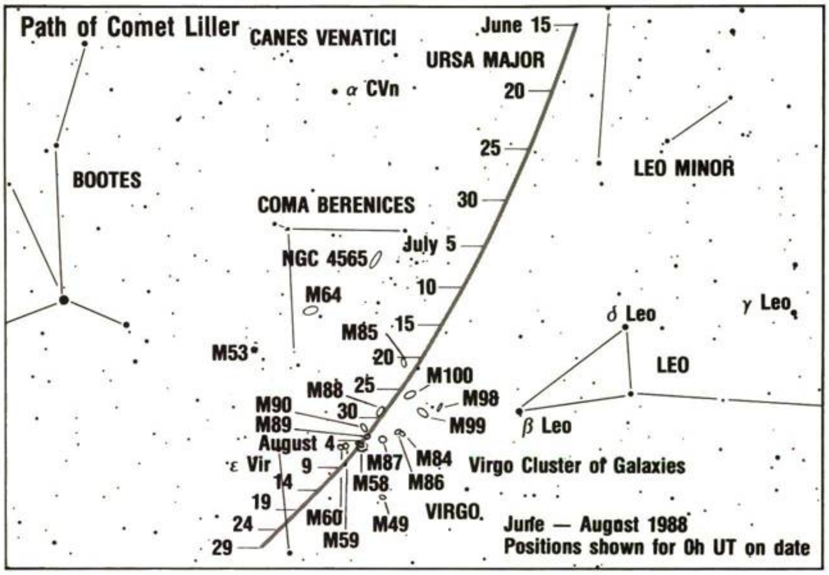
With an 8-inch or larger telescope, excellent seeing conditions, and a good finder chart, you might be able to identify Pluto moving slowly in Virgo. Pluto has an angular diameter of less than 0.2″ — much too small to be glimpsed observationally — and shines at magnitude 13.7.

Mercury reaches greatest western elongation in the morning sky on July 6, but is not well placed for telescopic observation. Despite an angular separation from the Sun of 21°, Mercury does not attain a high elevation this apparition. Wait until late October to spend much time observing Mercury.

Also in the morning sky we find Mars, which rises at local midnight early in the month and is visible for the rest of the night. During July Mars grows in apparent size from 13″ to 17″, and it brightens from magnitude −0.8 to −1.5. On September 27, Mars will reach perihelic opposition; that is, the Red Planet will be opposite the Sun in the sky while Mars is very near perihelion, its closest point to the Sun in its elliptical orbit.

You can expect Jupiter to be its usual dynamic self in the morning sky this month. Its disk grows from 34.7″ to 37.1″ during July, while it brightens slowly from magnitude −2.1 to −2.2. Can you discern any detail in either of the prominent equatorial belts? If you spot a large-scale narrowing of the South Equatorial Belt, it's probably the Great Red Spot.

In mid-March I observed Jupiter under moderately good seeing conditions twice in a week. On both occasions the Great Red Spot appeared to be redder than I've seen it in many years. It has been so lacking in red that it might have been called the Great "Very Pale Red" Spot. If I really saw a change in redness, does it signal a return to the good old days, when the Great Red Spot was a vivid orange? Jose Olivarez, Jupiter Recorder for the Association of Lunar and Planetary Observers, reports that the Red Spot has made several false starts in the past few years, so you shouldn't get your hopes too high. Stay tuned.


Path of Comet Liller

June — August 1988
Positions shown for 0h UT on date

JULY'S COMETS

Comet Tempel 2 is the only moderately bright periodic comet predicted to be visible for the remainder of the year, and as such it deserves your attention. However, there is another bright comet making its first recorded pass through the inner solar system. Comet Liller (1988a) is already fading in brightness but should be an 11th- or 12th-magnitude comet during July. In the middle of the month it passes through the rich Virgo cluster of galaxies, which will make for many interesting conjunctions.

JULY'S ASTEROIDS

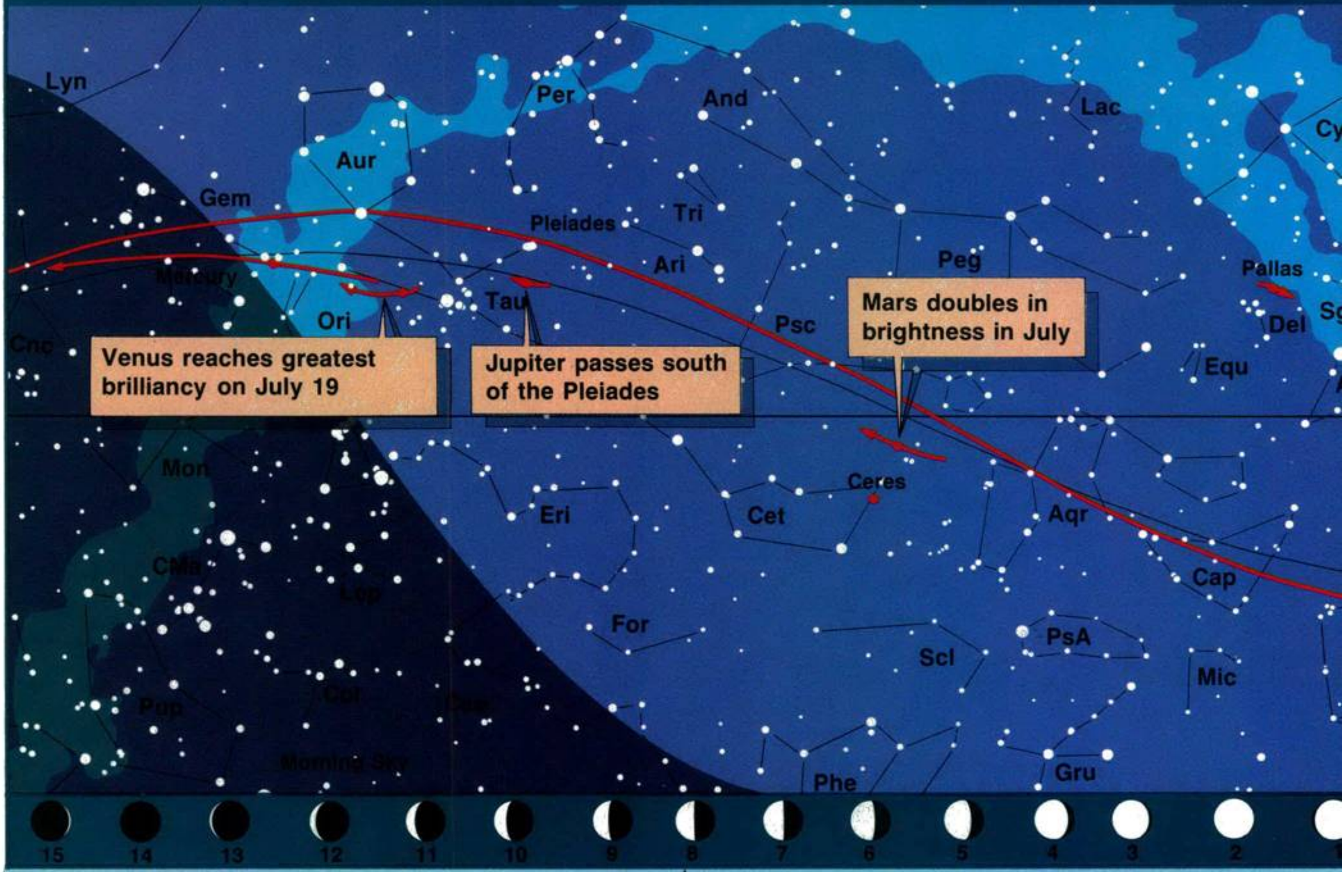
2 Pallas is a magnitude 9.6 object at mid-month, when it is visible under a dark, moonless sky with even a 2-inch telescope. To locate Pallas, plot the positions of the minor planet on a star atlas that reaches faint magnitudes, such as *Uranometria 2000.0*. Its positions are:

July 9	20h34m09.3s,	18°15′12″
July 13	20h31m18.1s,	18°05′50″
July 17	20h28m18.4s,	17°52′23″

1 Ceres, the first asteroid to be discovered, is a morning object in July. Look for this 8.1-magnitude object in Cetus at mid-month.

July 9	00h23m10.9s,	−10°56′14″
July 13	00h24m57.0s,	−11°03′03″
July 17	00h26m24.9s,	−11°12′06″

The Solar System July 1988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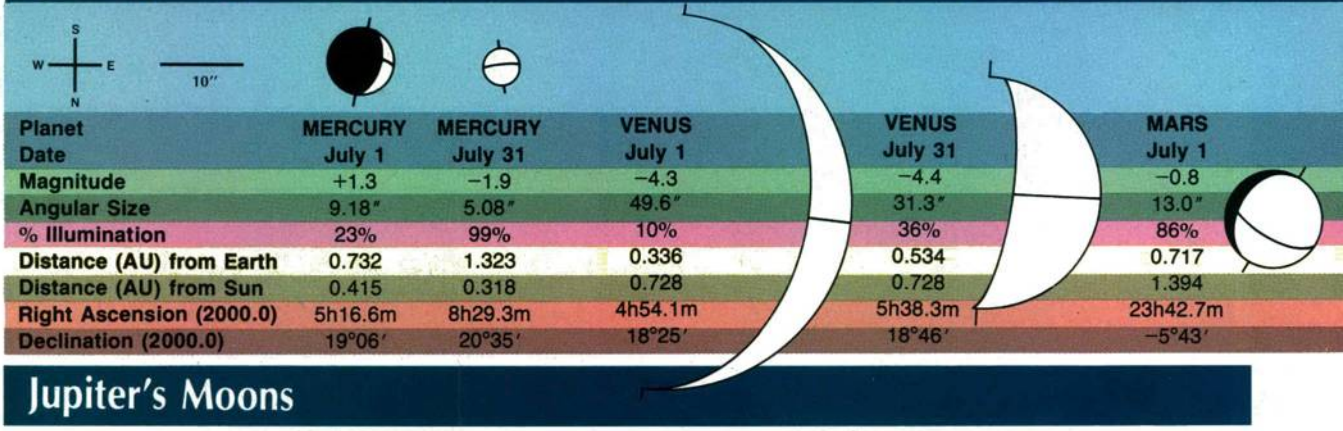
Venus reaches greatest brilliancy on July 19

Jupiter passes south of the Pleiades

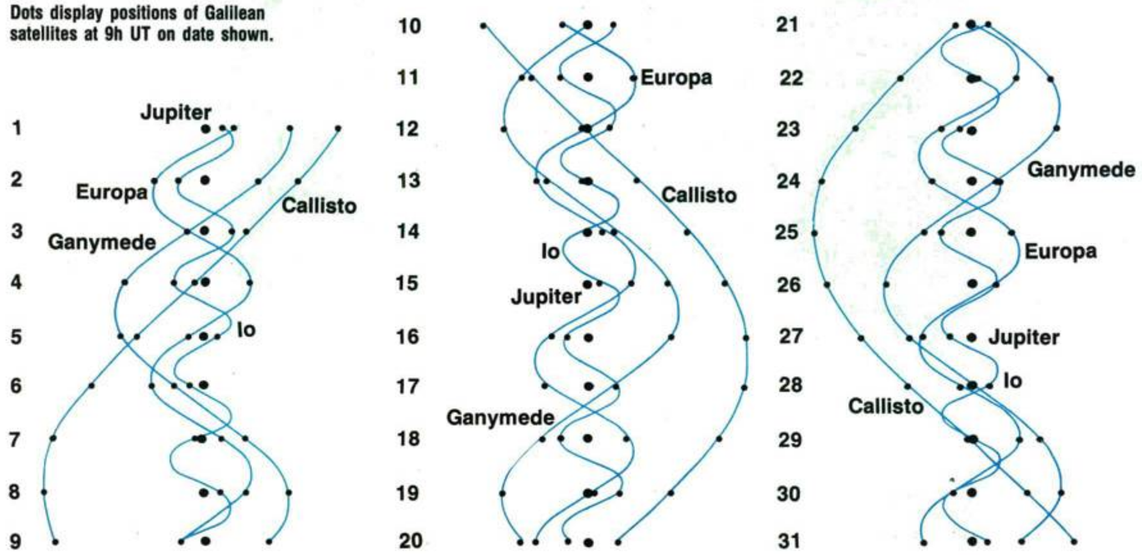
Mars doubles in brightness in July

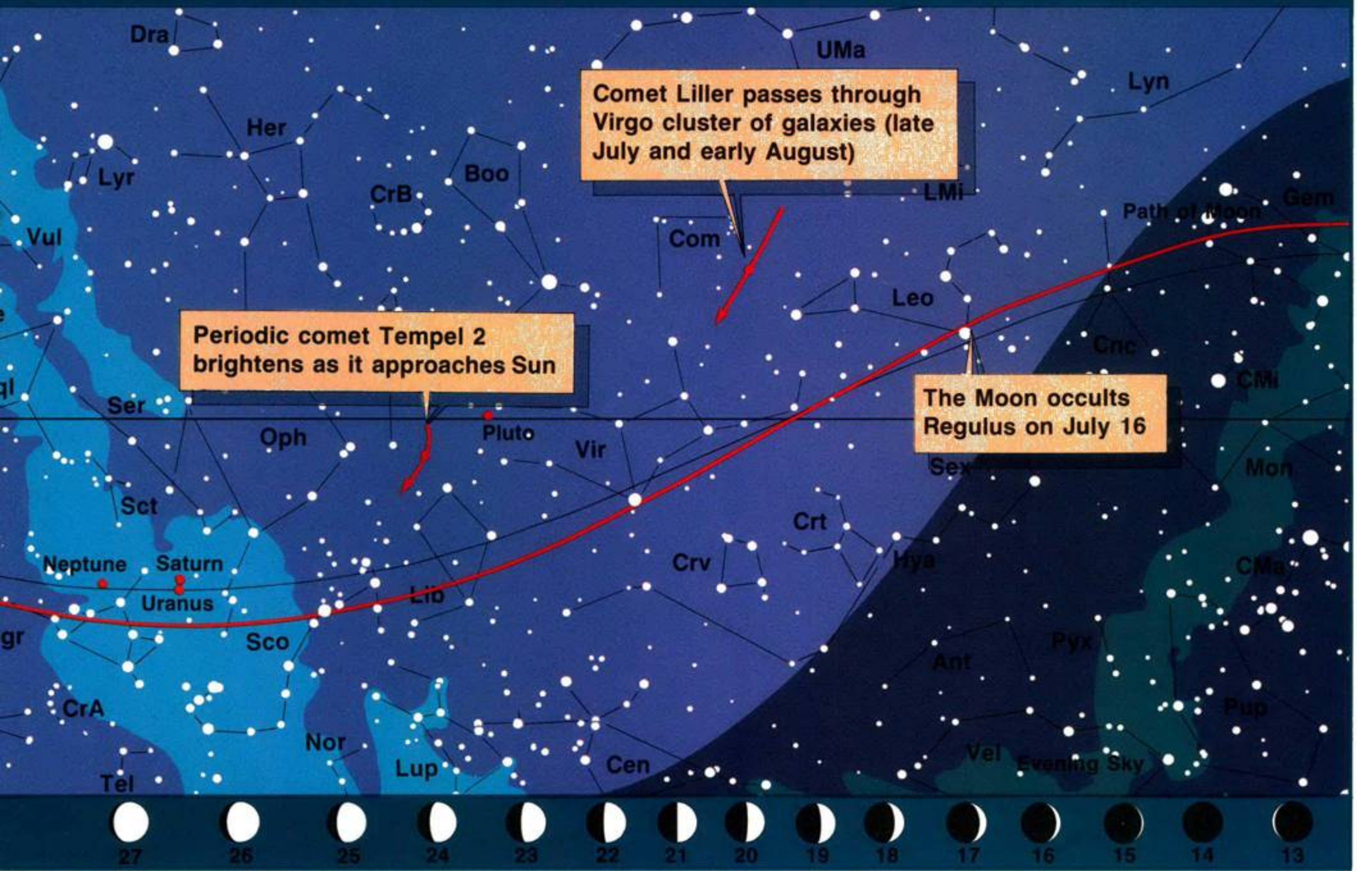


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	July 1	July 31	July 1	July 31	July 1
Magnitude	+1.3	−1.9	−4.3	−4.4	−0.8
Angular Size	9.18″	5.08″	49.6″	31.3″	13.0″
% Illumination	23%	99%	10%	36%	86%
Distance (AU) from Earth	0.732	1.323	0.336	0.534	0.717
Distance (AU) from Sun	0.415	0.318	0.728	0.728	1.394
Right Ascension (2000.0)	5h16.6m	8h29.3m	4h54.1m	5h38.3m	23h42.7m
Declination (2000.0)	19°06′	20°35′	18°25′	18°46′	−5°43′

Jupiter's Moons

Dots display positions of Galilean satellites at 9h UT on date shown.

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Lyr
CrB
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Pyx
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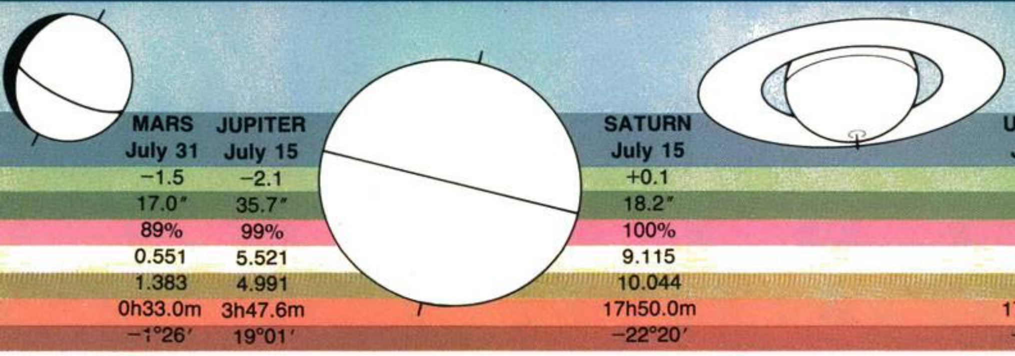
Comet Liller passes through Virgo cluster of galaxies (late July and early August)

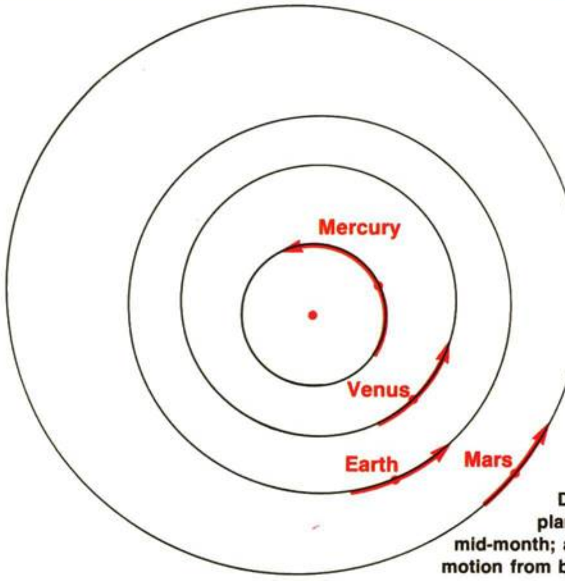
Periodic comet Tempel 2 brightens as it approaches Sun

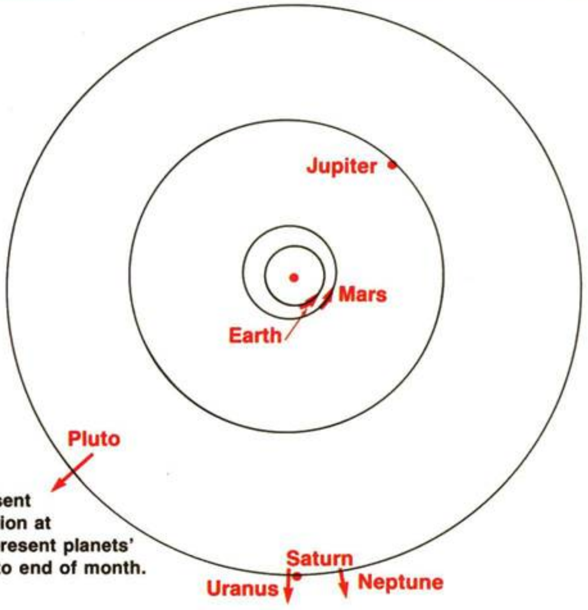
The Moon occults Regulus on July 16



MARS July 31	JUPITER July 15	SATURN July 15	URANUS July 15	NEPTUNE July 15	PLUTO July 15
−1.5	−2.1	+0.1	+5.6	+7.9	+13.7
17.0″	35.7″	18.2″	3.8″	2.3″	0.1″
89%	99%	100%	100%	100%	100%
0.551	5.521	9.115	18.356	29.238	29.362
1.383	4.991	10.044	19.284	30.224	29.664
0h33.0m	3h47.6m	17h50.0m	17h52.3m	18h37.1m	14h50.2m
−1°26′	19°01′	−22°20′	−23°39′	−22°11′	0°36′

The Planets in Their Orbits


Mercury
Venus
Earth
Mars


Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Dots represent planets' position at mid-month; arrows represent planets' motion from beginning to end of month.

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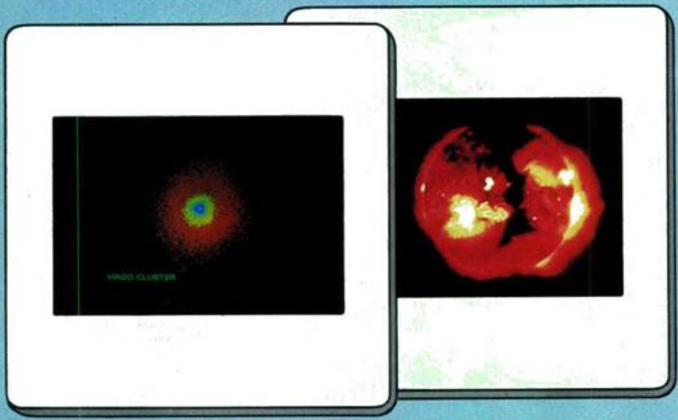

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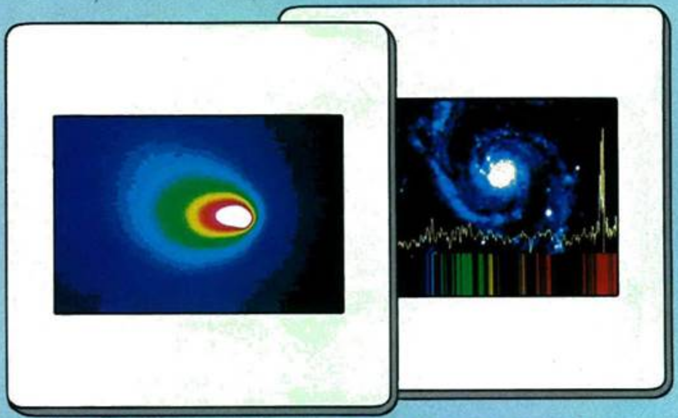

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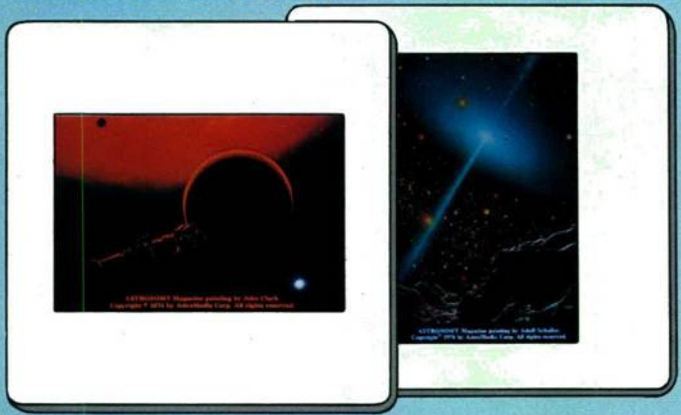

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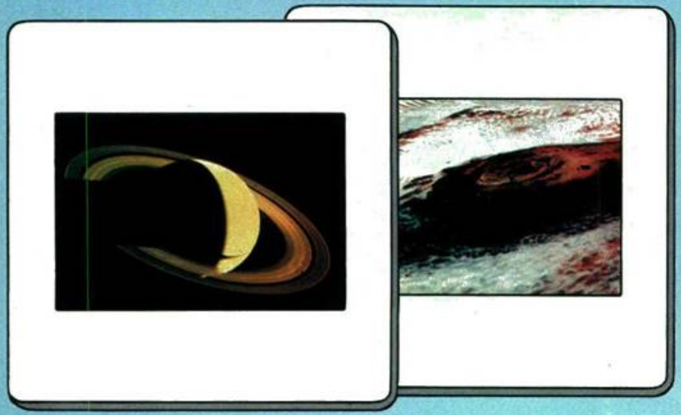

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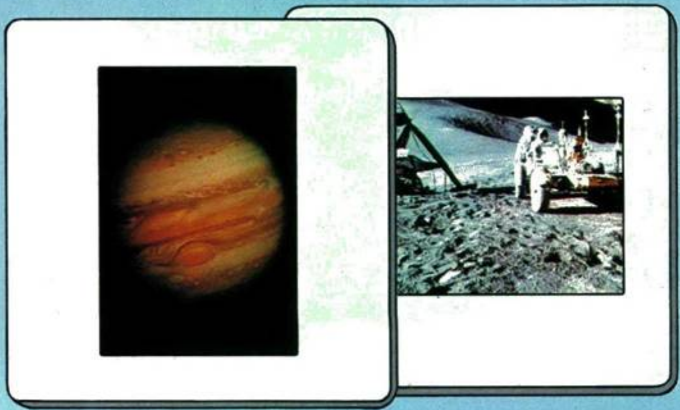

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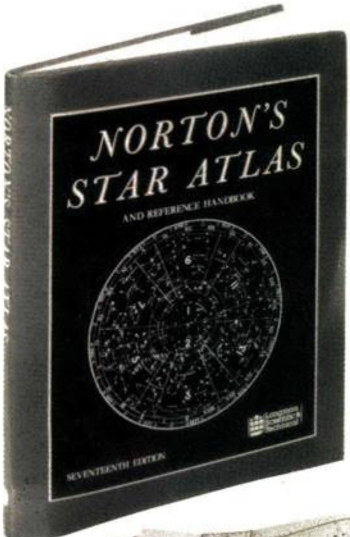

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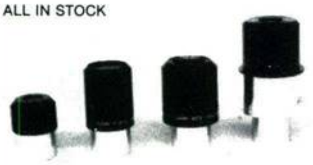

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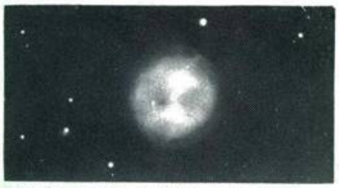

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The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount .. $45
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha	(MV)
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

LUMICON®

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For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

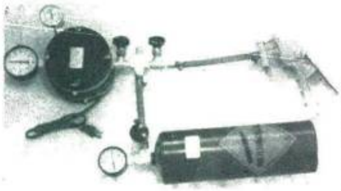
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller .. **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

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All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4.448.500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$89.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**

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For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
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GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)...... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures . **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $70
NEW Deluxe Digital Qtz. Drive Correc. **$298**

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NEW **SRV3200**

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LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica SR1600, very fast, fine gr.	24	$12.95
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

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LUMICON, 2111 Research Dr., #5
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NEW! NON-ROTATING HELICAL FOCUSER

LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6" telescope.
LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2" i.d. eyepiece holder. It has a vertical travel of 1¼" and a very low profile only 1½" high. It is CNC machined, black anodized, and a perfect match to LUMICON EASY-GUIDERS.

Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 20" OD, SUPER-FINDER base plate.

LUMICON Deluxe Helical Focuser ...	**$79.50**
3 handles (see photo)	**$12.95**
Helical focuser with 3 handles	**$92.40**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

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These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼" Basic Camera adapter, 2 part system	**$32**
0.96" Basic Camera adapter, 2 part system	**$32**
1¼" prime Focus adapter, fits 1¼" focuser	**$22**
0.96" prime Focus adapter, fits 0.96" focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER ...	**$169**
1¼" right-angle version, w/star diagonal	**$195**
2" right-angle version, non-rotating focuser ..	**$199**
1¼" Deluxe right-angle Super-Finder*	**$279**
2" Deluxe right-angle Super-Finder*	**$309**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$145**
1¼" Amici Prism diag. for correct left-right views	**$59.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc....	**$26.00**
2" adapter for Criterion 4000, 8000 ...	**$26.00**
2" adapter for C-80, C-90, C-100	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160 ..	**$59.50**

COMA CORRECTOR MULTIPLIER - 2" BARLOW

These custom-designed LUMICON lenses correct aberrations in f/4 to f/5 Newtonians, and thread directly into LUMICON 2" Easy-Guiders. The LUMICON Coma Corrector/Field Flattener improves photographic star images for fast Newtonian telescopes by correcting coma and flattening the field. Off-axis star images are much smaller, making off-axis guiding easier, and reducing the off-axis star image size in photos. The LUMICON Multiplier/Field Flattener multiplies the image scale by 1.8X (f/4.5 becomes f/8) with the included extension tube (1.5X w/o extension). The multiplier may also be used visually as a highly corrected 2" Barlow lens. Lens designs are optimized for f/4.5 and all surfaces are multi-coated.

48mm Coma Corrector/Field Flattener	**$285.00**
1.5X/1.8X Multiplier/Field Flattener .	**$195.00**
LUMICON 2" Easy-Guider (St. camera)	**$169.50**

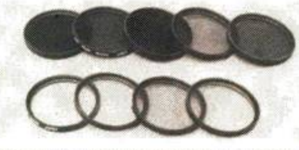
VIEWING ADAPTERS

2"/1¼" Adapter, threaded 48mm filters ..	**$20**
2"/T - Thread adapter, threaded 48mm ..	**$25**
T - Thread/1¼" adapter. Converts telephoto lenses for viewing as finderscopes	**$25**

EXTENSION TUBES

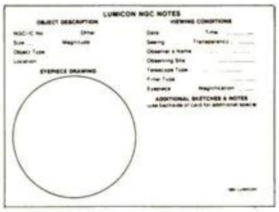
1.0" long Thread-in extension tube	**$12.00**
1-2½" long, threaded for 1¼" filters	**$16.00**
4½" long extension tube, 1¼" i.d.	**$25.00**
2" i.d. Extension tube, 3" long, threaded for 48mm filters, adds 1.6-3.0"	**$26.00**

48mm COLORED GLASS FILTERS



These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

Filter:	Bandpass	Trans	Price
Ultraviolet	320-420nm	85%	**$35**
Minus Violet	420nm-IR	96%	**$29**
Blue Tricolor	340-470nm	80%	**$35**
Hi Perf. Blue	300-540nm	95%	**$35**
Yellow	480nm-IR	98%	**$18**
Green	490-590nm	60%	**$18**
Orange	560nm-IR	98%	**$18**
Red	600nm-IR	98%	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**
Cyan	340-580nm	95%	**$59**



LUMICON NGC NOTES
OBJECT DESCRIPTION
VIEWING CONDITIONS
EYEPIECE DRAWING
ADDITIONAL SKETCHES & NOTES

NGC NOTES

These handy **NGC NOTES** are stiff 4"X5½" cards. the **NGC NOTES** fit in your hand and are ideal for making notes and sketches while observing at the eyepiece. Making sketches **greatly improves** your observing skills and also gives you a permanent record. Get 200 **NGC NOTES** for Messier objects; NGC object observers should get 400-800 **NGC NOTES.**

NGC NOTES, Pack of 200 .... **$9.95**
Pack of 400 **$17.95** Pack of 800 **$32.95**

Meade® TELESCOPES AT LUMICON

8" w/LX3 Drive $979

NEW! 2080/LX5 w/MCOG $1589
MEADE 2120/LX5 w/MCOG ... $1999

The most advanced Schmidt-Cassegrain telescope available! *Standard equipment* includes dual-axis hand-held electronic command center, 2" mirror star diagonal, 9X60mm polar viewfinder, multi-coated/enhanced optics, 26mm Super Plossl, tripod and wedge.

#39 Electric declination for 2080 or 2120/LX5	**$109**
Dew shield-essential 8" (#712) **$65**; 10" (#710)	**$98**
Accessory shelf for field tripod ($40 list)	**$28**
LUMICON EASY-GUIDER/Rich-Field viewer: for 2080 (f/6 operation) **$225**; for 2120 (f/4-f/10 operation)	**$395**
Computer control system, 8000 object memory	**$1495**

8" LX5
$1589
8" LX3
$1389
10" LX5
$1999
10" LX3
$1799

Meade 8" Model 2080/LX5: Shown with *standard-equipment* 9X60mm finder, dual-axis controller, 2" Diagonal Mirror, Equatorial Wedge, Field Tripod.

NEW! MTS TELESCOPES

6" $589 w/Motor
8"
$979
w/LX3
Drive
10"
$1739
MCOG & Drive

Meade 8" f/10 & 10" f/10 MTS Schmidt-Cassegrain Telescopes
Standard equipment: 8" f/10 Schmidt- Cassegrain includes LX3 Quartz drive system, 1¼" star diagonal, MA 25mm 1¼" eyepiece and 6X30mm finder. Schmidt-Newtonians include LX3 Quartz drive (MTS-SN8) or #788 motor drive (MTS-SN6), MA 25mm eyepiece and 2"/1¼" helicoid focuser.

Optional MCOG Coatings add 20% trans. 6" **$49** 8"	**$69**
MTS-SN6, 6" f/5 Schmidt-Newtonian, #788 drive ...	**$589**
MTS-SN8, 8" f/4 Schmidt-Newtonian, **w/LX3 drive** .	**$979**
MTS-SC8, 8" f/10 Schmidt-Cassegrain **w/LX3 drive**	**$979**
MTS-SC10, 10" f/10 Schm-Cass **w/MCOG, #788 drive**	**$1739**
#36 LX3 Hand Controller and #38M Dec. motor (SC8)	**$189**
#36 LX3 Hand Cont., #38M Dec. motor, brackets (SN8)	**$259**
#43 Drive Corrector (runs #788 off a 12VDC battery)	**$99**
8X50mm finder (MTS-SN8) **$88**; 6X30mm (MTS-SN6)	**$56**
#109 Setting Circle rt. ascension & dec. w/pointers ..	**$39**
#38M Dec. motor system for SN6	**$155**

See below for detailed viewing and photography options.

4" MEADE 2045 w/table tripod $595

4" f/10 Meade 2045/LX3 w/quartz drive	**$795**
#36 dual-axis cont. (LX3) **$99,** #38A dec. motor	**$99**
Wedge & field tripod for Meade 2045 ($380 list)	**$298**
Dew shield ($80 list) .... **$55;** Solar Filter	**$95**

FILTERS STOP POLLUTION

LUMICON UHC Filter™ for nebulae. Standard 1¼"	**$79**
Prem 1¼" **$99;** Std 48mm **$159.50;** Prem 48mm	**$199.50**
LUMICON Deep-Sky Filter™, 1¼" Premium ...	**$79**
48mm Prem Deep-Sky **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼" eyepiece	**$20**

PHOTOGRAPHY ACCESSORIES

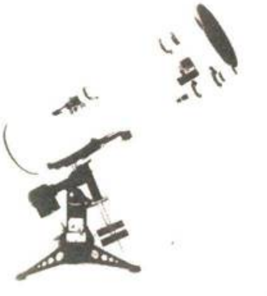
LUMICON Newtonian Easy-Guider, 1¼" or 2"	**$169**
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX5 and 2080/GEM (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$89.50**
Dual-axis Drive corrector	**$219**

These Meade Telescopes are complete and ready for viewing.

They include telescope with all coated optics for high transmission, mount, tripod or pier with legs, motor drive (except models 6600, 8800, GEM series). Finderscope, at least one eyepiece, and complete instructions. Call or write LUMICON for full technical information. MCOG means multi-coated enhanced optics group.

MEADE NEWTONIAN TELESCOPES

16" f/4.5
MEADE
DS-16A
only
$1899



Note: Astrophotographers should order optional sealmaster ball bearings for the DS-16A (add $229).

Model 6600, 6" f/5 w/1¼" focuser, 6X30 finder	**$685**
Model 628c, 6" f/8 w/motor, 2" focuser, 8X50 finder	**$798**
Model 645c, 6" f/5 w/motor, 2" focuser, 8X50 finder	**$829**
Model 8800, 8" f/4.5 w/1¼" focuser, 6X30 finder	**$895**
Model 826c, 8" f/6 w/motor, 2" focuser, 8X50 finder	**$975**
Model DS-10A, 10" f/4.5 w/motor, 2" focuser ..	**$995**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser .	**$1975**
Sealmaster ball bearings for DS-16A, recommended!	**add $229**
Finderscope for DS-10A, DS-16A, 8X50mm incl. mount	**$109**

All foreign orders add 6% ($8 minimum). California residents add 6% tax. Prices subject to change w/o notice. Set Meade and LUMICON Catalogues $4. **LUMICON, 2111 Research Dr., #5, Livermore, CA 94550.** Call **(415) 447-9570** for information & orders. Store Hours: M-F 9am-5pm; Sat 11am-3pm. All telescopes shipped F.O.B. Livermore.

SPECIAL REPORT

Eclipse Tales from the South Pacific

Intrepid eclipse observers had to outmaneuver the clouds to witness 1988's big event.

CLOUD DODGING IN THE PHILIPPINES

"I think we've got to run for it," I said to Andy Steinbrecher. It was 6 a.m. on March 18, the day of the total solar eclipse, and from Davao City on the isle of Mindanao in the Philippines we saw clouds, lots of clouds covering more than half the sky.

"Let's give it fifteen more minutes," Andy said.

But the cloud cover got only worse as the Sun got higher. We left at 6:20 a.m. Even if all went well we would be cutting it close. First contact would be at 7:51 a.m. and totality at 9:03 a.m.

Because of local political unrest, the entire path of Philippine totality had been deemed unsafe for travelers, but Davao was considered the least dangerous place in the track. From there we headed out across ninety miles of reportedly hostile territory toward General Santos, the only other city in the path.

Our decision to hightail it overland was not as reckless as it sounds. Though the U.S. State Department advised Americans against travel to Mindanao, a spokesman for the Moro National Liberation Front, a Moslem group seeking independence from the Philippines for Mindanao, promised a truce for March 18. And the Philippine people assured us that we were welcome in their land. Besides, there was a better chance for clear skies in General Santos than in Davao, and the eclipse in General Santos would last longer. Maximum totality, which could be seen from somewhere in the mid-Pacific, would last three minutes and forty-six seconds. General Santos would get three minutes and twenty-two seconds, while Davao would get only two minutes and fifty seconds.

Our driver, Roger Bague, raced through lush countryside over the two-lane National Highway, speeding through stop signs and faithfully observing what seemed to me to be the only traffic law in the country: blowing the horn at oncoming Jeepneys, buses, and motorized tricycles you're overtaking, cars overtaking you, pedestrians, water buffalo, chickens — everything on the road.

After we passed through a rainstorm that was heading back the way we'd come, we found Sun and clear sky and a splendid rainbow in the mountains beyond. That was a good sign.

Five or ten miles outside of General Santos, with partial phases well under way and totality forty minutes off, we pulled into a field next to a walled agrarian compound. Andy set up his photographic gear under almost cloudless skies, while I made friends with the locals.

Totality was twenty minutes away. But the temperature had fallen enough that the warm air released its moisture and new clouds formed at the horizon and rose toward the Sun at fast-forward speed, like clouds in a Steven Spielberg movie.

"We have to go," Andy said.

So we drove on, tearing into General Santos with the horn blasting, looking frantically for a place to set up. The air had already taken on an eerie, lemony hue when we skidded into an empty field. It was about two minutes before totality, and by then the Spielberg clouds covered more than 90 percent of the sky.

"I think we're clouded out," I said.

Our plight was shared by at least 150 Filipinos who'd seen us tear into the field and followed us.

Suddenly Andy yelled, "There's a big hole coming up!"

The gap in the clouds reached the Sun, and the last sliver of sunlight sparked out. Everyone stopped breathing. The corona burst bright, and the most extraordinary prominences we'd ever seen flashed from the limb of the Sun. We stood in glory under at least three minutes of totality before the hole in the clouds passed us by.

Observers back in Davao were not only clouded out, they were rained out. Just a few people there saw the eclipse at all, and the fortunate few saw it for only five or six seconds through a thick filter of clouds.

— *James Ehmann and Andrew Steinbrecher*

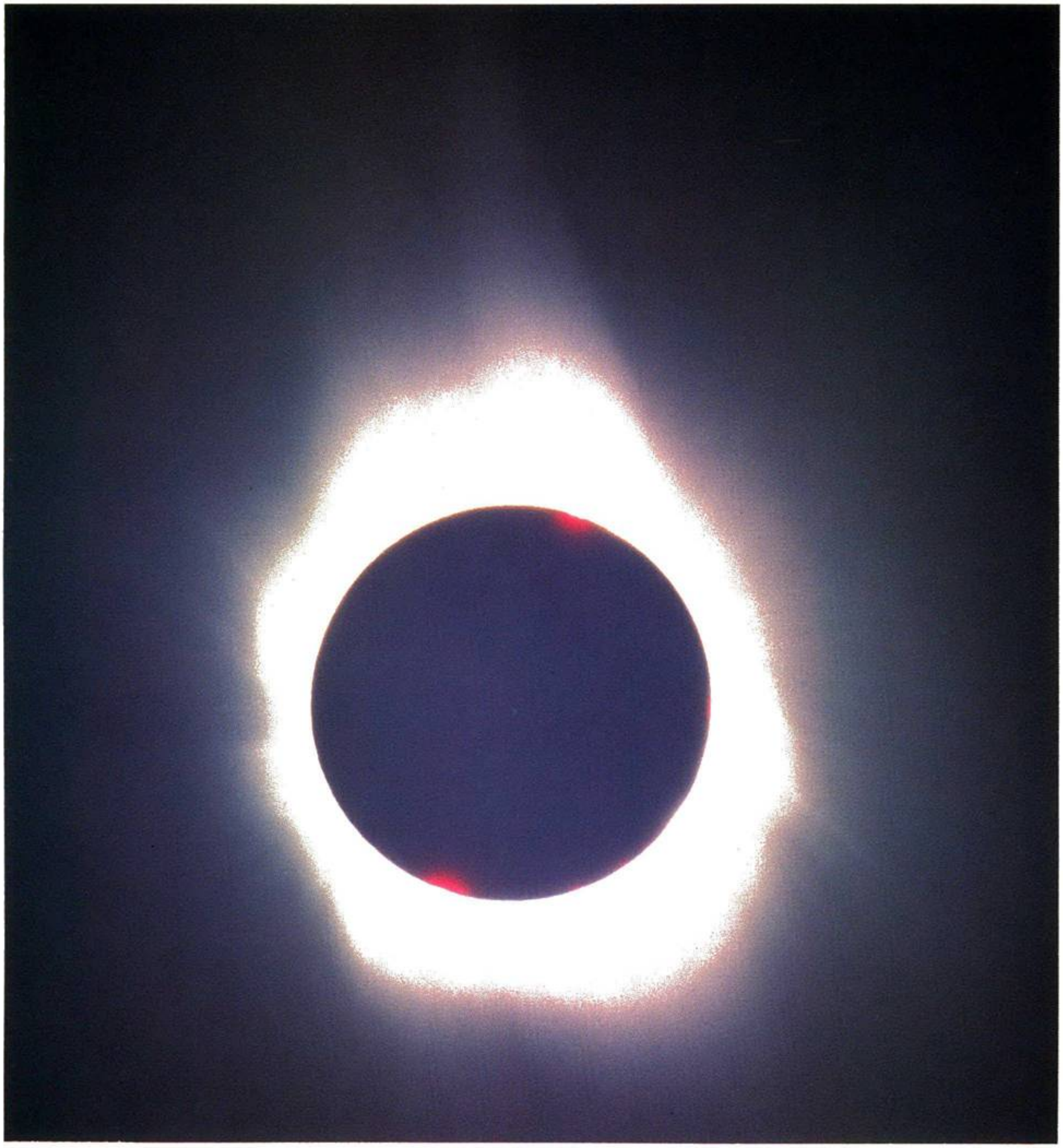
ABOARD THE QUEEN ELIZABETH 2

When the power supply of the *Queen Elizabeth 2*'s satellite-aided navigation equipment blew several days before the eclipse, the captain and crew resorted to star and land sitings to get the *Queen Elizabeth 2*'s one thousand eclipse seekers to the path of totality.

To help us find a good viewing location, eclipse meteorologist Edward Brooks of Boston College talked to experts on land and at sea for days in advance. Because the mid-Pacific is plagued by "the doldrums," Brooks visited the weather organization at the Singapore Airport and extrapolated from past weather patterns to predict the weather during the day of the eclipse.

On the eve of the eclipse he stayed up on the bridge all night to work with the navigator to steer us successfully to a good location. We viewed the eclipse in the Java Sea between Borneo and Sumatra near longitude 108° east and latitude 2° south.

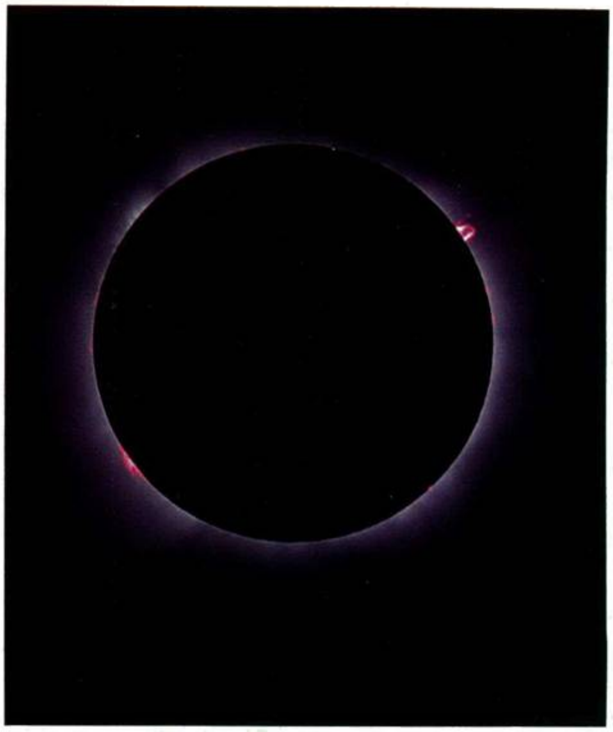
During totality the ship's engines were stopped, and the 67,000-ton ship didn't rock noticeably. There were



Queen Elizabeth 2

THOUGH CLOUDS INTERFERED at times, passengers aboard the *Queen Elizabeth 2* (left) and workers at a Philippine farm observed at least part of the eclipse with Solar Skreen®.

LOCAL TRIBES in ceremonial costumes entertained eclipse travelers visiting the Philippines. Glenn Schneider, who built a throwaway eclipse telescope (right), observed the "eclipse of the magnificent prominences" (top right) from Indonesia.



many scattered clouds during the partial phase, but we viewed totality through a clear spot with only haze or very thin cirrus clouds in front of the Sun.

Baily's Beads were visible at third contact, though I missed seeing them because I had to keep warning passengers about looking at the eclipse with binoculars. Some passengers made videotapes of the eclipse; others stayed in bed and watched the event on the closed-circuit television monitors in their cabins.

— Stephen P. Maran

TOTALITY WITH PRESIDENT AQUINO

I viewed the eclipse with Corazon Aquino, president of the Philippines, and about twenty other people plus Aquino's generals and guards at the San Miguel hybrid corn farm twenty miles from General Santos.

President Aquino arrived at the plantation in a helicopter. She was very excited about seeing the eclipse, and I think this was the first total eclipse she ever saw. I didn't get to talk to her very much, though she was very gracious when I gave her some Solar Skreen® to view the eclipse with.

Just before totality, clouds moved in, so we missed most of that phase of the eclipse. After the eclipse the people who viewed the event at the plantation were served a buffet lunch under a tent. The site was ringed with army helicopters and soldiers with their weapons ready.

The town of General Santos bent over backwards to put on parades, craft shows, and native dances for tourists visiting the Philippines. The high point was a barrio fiesta on the night before the eclipse, which included dances, songs, and skits performed by tribes in the area. In one dance a girl wrung the neck of a live chicken and drank the chicken's blood as part of a marriage ritual.

— Roger W. Tuthill

MY SPECIALLY DESIGNED ECLIPSE TELESCOPE

I witnessed my fourteenth eclipse from Bangka Island, Indonesia, with a mostly disposable telescope I built for this eclipse. I came up with the idea while I was preparing for the trip and was once again caught between wanting to bring everything but the kitchen sink and staying within the maximum baggage weight allowed on international flights.

I wanted to photograph the eclipse with a surplus 4-inch f/12 Nikon achromatic refractor objective. This lens has given me stunning, high-contrast views of the Moon and planets, and I was dying to try it out on a total solar eclipse. But lugging the refractor and mount 12,000 miles seemed impractical.

So I built a lightweight, low-cost, throwaway telescope to hold the objective. Everything but the optics and the focusing mount was expendable. I intended to return to the United States with about twenty pounds less than I started with.

I built the telescope, essentially a low-profile Dobsonian refractor, in my basement over a weekend. The lens, built in a rectangular tube, was intended to photograph prominences and the inner corona. Piggybacked on the main scope was a 260mm f/5.6 wide-field lens and camera to photograph the second- and third-contact diamond rings. For stability I brought three long, threaded bolts that could be pounded into the ground.

Because the telescope was low to the ground, I had to lie down to observe and photograph the eclipse. This was actually quite comfortable. Following the Sun without a drive was particularly easy because the eclipse occurred two days before equinox and my observing site was just south of the equator. The Sun rose due east and had virtually no azimuth motion as it crossed the sky. In retrospect the Dobsonian altazimuth mount may not have been necessary; an "alt" mounting would have sufficed.

— Glenn Schneider

UP THE MIGHTY MAHAKAM RIVER

Exotic images of dense, steamy jungles, head-hunters, and riverboats right out of *The African Queen* drove me to plan an eclipse expedition to Borneo. Even if I got clouded out, a trip through Borneo would be exciting and worthwhile by itself.

I chose an inland site about 150 miles northwest of Samarinda, the capital of Indonesian Borneo, which could be reached by way of the mighty Mahakam River. What I didn't know was that the Mahakam is one of the most crooked rivers in the world and that the actual distance to the observing site would be about 370 miles.

A 22-meter river longboat, the *KM Lauk*, would be our home for eight days. We made slow progress against a strong river current. Eventually we reached the vast, shallow Lake Jempang. Freshwater dolphins escorted us to a Banuaq Dayak village, where we were greeted with a lavish welcoming ceremony.

The Dayaks, once fierce head-hunters, are now friendly and entertained us with ritual dances in colorful costumes. That night we had uncomfortable accommodations in a Dayak longhouse. Our mosquito netting was so heavy I was sure no air could pass through, and the room was 100° Fahrenheit. In addition, at around 2 a.m. the tribe's medicine man prescribed one hour of vigorous drum beating to treat a patient, which didn't help us sleep.

Our longboat was taken across the lake to return to the Mahakam River. It traveled all night, getting farther upriver than we were. The next morning it took us three hours under a hot Sun to reach our longboat and the Mahakam. After traveling all day we arrived at Longiram, which was within the path of totality.

The farther we got, the narrower, swifter, and more treacherous the river became. Numerous whirlpools appeared and we frequently had to navigate around rocks and sandbars.

We then began to scout for suitable eclipse sites and decided on a logging camp that had a level knoll with a clear view to the east.

The next morning there were threatening areas of low fog, but since there was nowhere to run we set up our eclipse paraphernalia. The fog lifted just before first contact, and a few blue patches of clear sky gave us some hope. Thirty minutes before totality the temperature was 85° Fahrenheit. There was no wind, but the clouds continued to be bothersome.

At totality the chromosphere was fantastic though the outer corona was not visible because of the clouds. We saw two large pink prominences, diametrically opposite each other. One was a heart-shaped loop surrounded by a matching coronal loop and the other was like a mushroom with sharp protuberances. No words or photographs can ever express what a fantastic sight this was.

— Jacques Guertin

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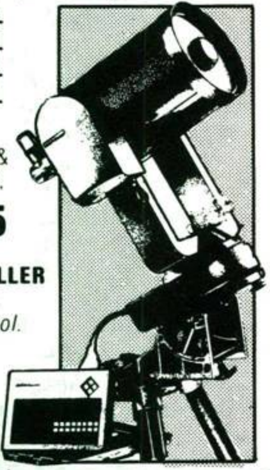

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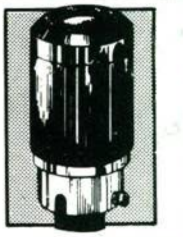

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READY, COMPUTE, AIM

Punch in a celestial object's coordinates, let your pocket computer crunch the numbers, and then aim your Dobsonian.

by Bill Burton

The idea behind computer-aided telescopes is so simple you can make one of these telescopes yourself. All you're doing is converting right ascension and declination into altitude and azimuth — pointing directions for a Dobsonian telescope.

The simplicity of a computer-aided telescope was demonstrated to me a couple of years ago when I was observing with my friend Dick Suiter in Ohio. An amateur astronomer with a bent for physics, Dick was attempting to use his new programmable calculator to point a small altazimuth reflector telescope. He had attached dime-store protractors to the rocker and side bearing on the mounting.

He first made sure that the telescope was level and then located a reference star. He computed the star's altitude and azimuth and then adjusted the protractors so they matched the read-out from the calculator. I watched him do this, incredulous.

Dick next punched the equatorial coordinates of a bright Messier object into his calculator, ran a short program, and the calculator computed the altitude and azimuth of the new object. He turned the telescope until the angles on the protractors matched the numbers on the calculator and looked into the eyepiece. To my amazement (and his too!), the Messier object was in the field!

It seemed so easy. Inspired by Dick's demonstration, I decided to add computerized setting circles to my Dobsonians. Although I'm neither mathematically inclined nor a fanatical telescope builder, I succeeded in making computerized setting circles work on a small rich-field telescope, on my 17.5-inch reflector, and on my local club's 20-inch reflector.

Hidden Advantages

Computer-assisted finding has lots of advantages, though not all of them are obvious. The most important advantage is being able to find more celestial objects in less time than you can by dead reckoning or star hopping. If you spend five minutes or so finding a galaxy or cluster and two minutes looking at the object, you might manage to observe eight or nine objects per hour. With computer-assisted finding, you'll be able to find twenty an hour — and that includes a good two-minute look at each object. If you're pushing for some kind of record or doing the Messier marathon, you might be able to reach thirty objects an hour.

A COMPUTER-AIMED TELESCOPE carries a surveyor's compass and inclinometer for pointing precisely at sky objects.

A considerably less obvious advantage is that you have to take fewer reference materials like star atlases into the field. All you need is a list of coordinates for the objects you want to observe and one detailed back-up atlas for locating extraordinarily faint objects. The net result is that you'll save time fumbling with flashlights and books in the dark and have more time for observing.

You'll also be able to find things you didn't think you could. I find it challenging — and fun — to pick up stars and planets before it's fully dark. While the guys with equatorial mounts are still setting up, you can be looking at bright double stars or the planets.

Perhaps the least obvious benefit of a computerized Dobsonian is that the telescope enhances daytime observing. Have you ever seen the huge, thin crescent of Venus when Venus is near inferior conjunction? Have you ever seen Mercury high in the sky, well away from haze and turbulence near the horizon? How about spotting the stars in Orion's belt in mid-July? These things are all possible with a little help from a computer.

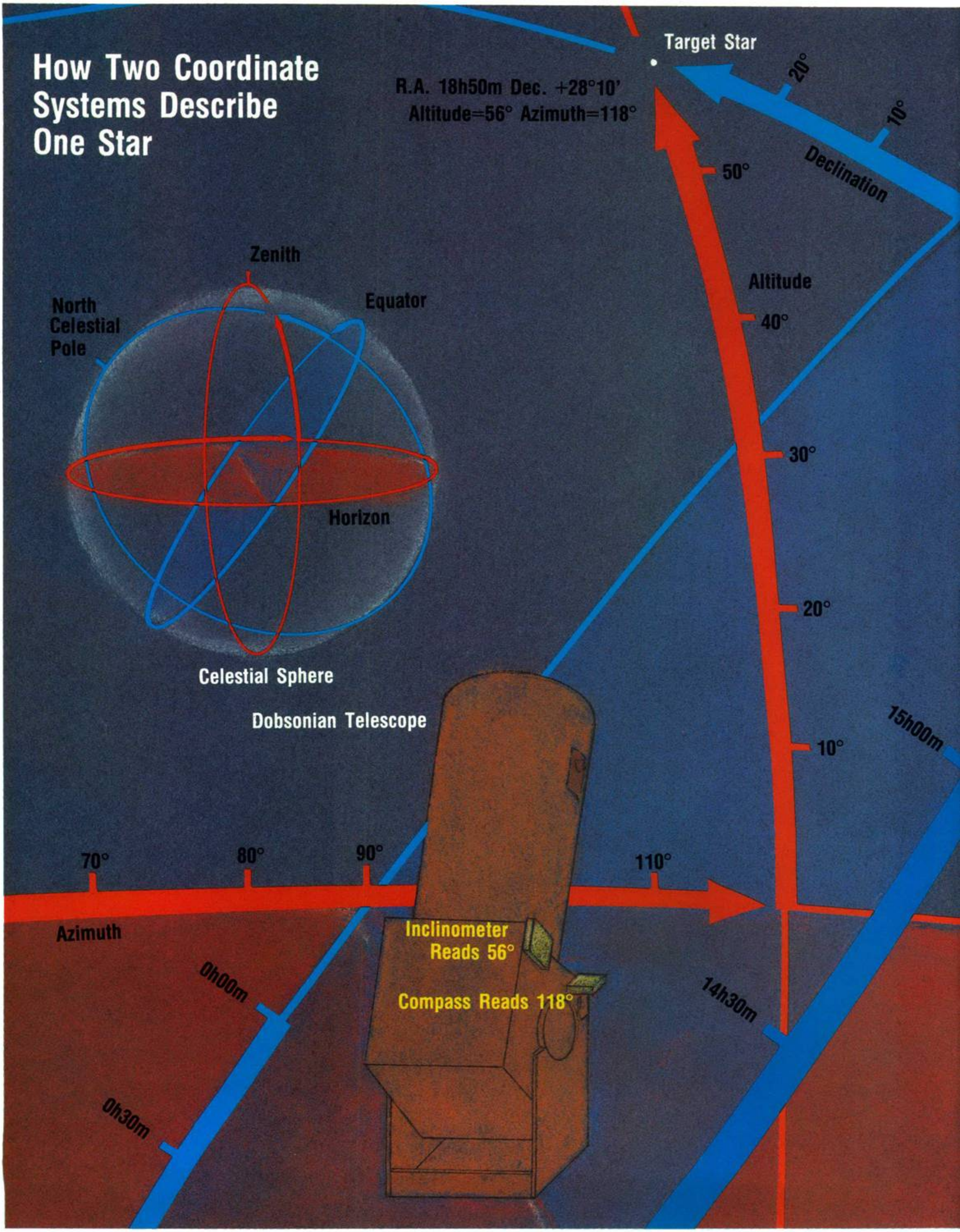
How Computer Finding Works

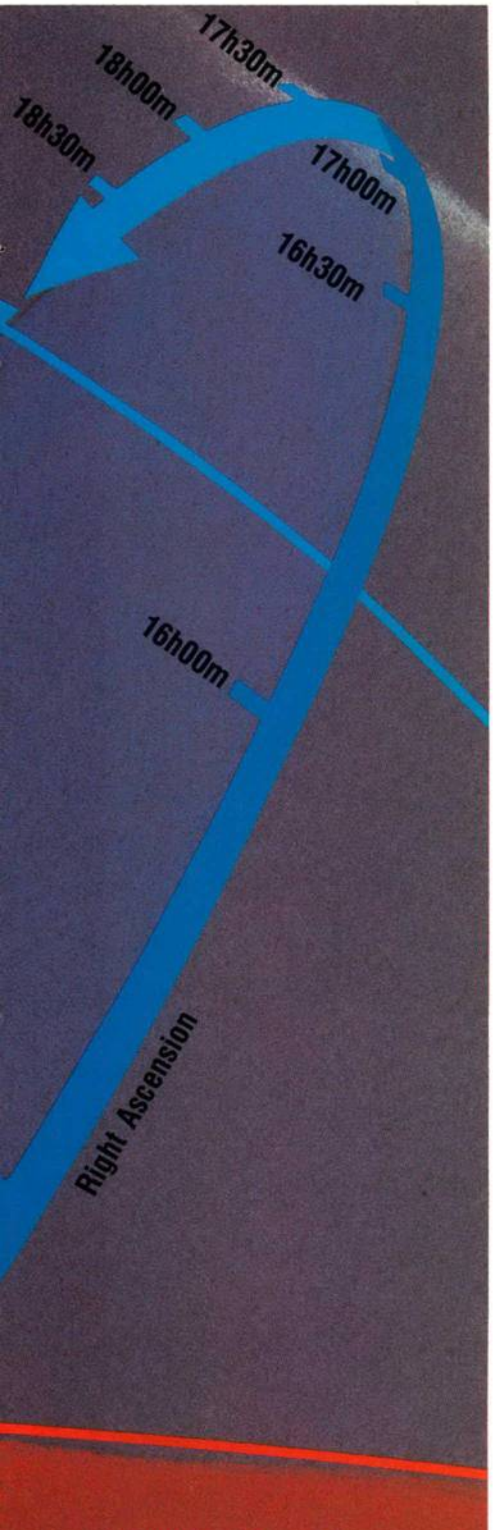
The equatorial coordinate system (right ascension and declination) and the horizon coordinate system (altitude and azimuth) are nothing more than two different ways of specifying the position of a star, much as dollars and pounds sterling are ways of measuring monetary value. If you know how the two systems are related, you can convert from one system to the other.

For monetary units you multiply the exchange rate times the amount of currency; for coordinate systems the "exchange rates" are the angles between the two systems, which are specified by the observer's latitude and the rotational position of Earth relative to the stars. Because a portable computer can handle all the math involved, this conversion is painless.

However, before you can convert equatorial to horizon coordinates, it's necessary to "freeze" the spinning Earth, that is, to compute Earth's rotation relative to the stars. An object's hour angle is its distance east or west of the meridian, and this is the angle the coordinate conversion routine really needs. The hour angle equals the

How Two Coordinate Systems Describe One Star


Target Star
R.A. 18h50m Dec. +28°10'
Altitude=56° Azimuth=118°
20°
10°
Declination
50°
Zenith
North Celestial Pole
Equator
Altitude
40°
30°
Horizon
20°
Celestial Sphere
Dobsonian Telescope
15h00m
10°
70°
80°
90°
110°
Azimuth
Inclinometer Reads 56°
Compass Reads 118°
0h00m
14h30m
0h30m



TO FIND A STAR with a compass and an inclinometer, convert the star's position in equatorial coordinates (shown in blue) to the horizon coordinate system (in orange). Because the coordinate systems are descriptions of the star's position, you can find the equivalent coordinates in the other system with a pocket computer.

object's right ascension minus the sidereal time at Greenwich plus your longitude west of Greenwich. A program in the computer calculates sidereal time from the date and civil time, so you only have to worry about entering these quantities correctly.

I bought a hand-held computer to carry out these coordinate and time transformations. I chose the Sharp 1250A (also sold as the Radio Shack PC3) because it's inexpensive and uses BASIC. (I understand BASIC better than the step logic most calculators use.) With the aid of a friend, John Kerns, I wrote a coordinate conversion program. It works beautifully. All you have to do is load it into the computer.

Pointing at the Right Spot

Shortly after Dick Suiter proved that computer finding worked, I attached protractors to the mount of my 4-inch RFT: one to read the azimuth (left to right) angle and one to read the altitude (up and down) angle. Wow — it worked! It was great! That first night I found a dozen objects easily in light-polluted skies. I wanted to add this feature to my 10-inch and 17.5-inch telescopes, but I hit a snag.

It's easy to attach protractors to a small telescope, but as telescopes get larger, the azimuth protractor gets buried deeper and deeper inside the rocker. Setting altitude was no problem, but I needed another way to set azimuth.

Then one day my wife's uncle showed me his surveying equipment. There, atop his transit, was a surveyor's optical compass. This is not your ordinary Boy Scout compass — it's a precision compass with a built-in magnifier to eliminate reading errors. I was amazed at its accuracy.

I could hardly wait for dark. We held his compass on the sideboard of my rich-field telescope, punched up some coordinates, and rotated the telescope into position. When I looked in the eyepiece, the object was at the edge of the field. The next morning I ordered my own compass.

The surveyor's compass is a super device. I use a Suunto model #360-R compass ($55 from Howard Sutton Co., 121 East 24th Street, New York, NY 10010). Its pointer is always accurate because there is only one way you can read it: through a magnifying peep sight. Because you can mount it on the telescope at eye level (a protractor must basically be under the telescope), a compass is far more convenient than a protractor.

For altitude, I recommend the Suunto surveyor's inclinometer (also $55 from Howard Sutton Co.). Surveyors use their inclinometers to measure altitude. Like a compass, an inclinometer eliminates errors in reading the results. You can place an inclinometer anywhere on the side of the tube. However, if cost is a factor, you can postpone buying an inclinometer and use a protractor instead. A good quality draftman's protractor, placed in the center of the altitude bearing, serves adequately, though you may need to search up and down a bit to find objects.

The best and safest way I've found to mount the compass and inclinometer is in brackets. I attach the compass bracket to the Dobsonian rocker and the inclinometer to the telescope tube. Construct a tight-fitting wooden box for each instrument with an opening so you can read the scale. Attach the box to an arm about eighteen inches long, and bolt that to the rocker box or telescope. The box protects these delicate measuring instruments, raises them to a comfortable viewing height, and keeps them away from residual magnetic fields in the telescope structure.

Because surveying is done during the day, the surveyor's compass is unlighted. I solved this problem by lighting the dial with a red light-emitting diode (LED) and two batteries. The lamp and batteries are built right into the compass and inclinometer holding brackets.

By the way, if you attach the compass and inclinometer to your telescope with brackets as I did, you can move these instruments from one telescope to another. They can be bolted onto any telescope made to use them.

Number Crunching

Pocket computers are ideal for doing coordinate conversions. The only drawback is that they may not work correctly in very cold weather. (But this drawback applies to any computer and most observers too!) A hand warmer or inside coat pocket can take care of the problem.

We wrote a program for pocket computers (see page 74) that does four things. There's an initial section for entering the date, latitude, longitude, and time zone. The next section lets you key in the right ascension and declination of an object and the time read from your watch; then it computes the altitude and azimuth. Another section lets you recall an object's coordinates from computer memory and computes the altitude and azimuth. Finally, there's a section for putting coordinates into the memory.

On tiny computers like mine, memory is precious. Even so, my 1250A can store the program and the positions of 225 celestial objects. With

```
10:"A" INPUT "MONTH #?"
   ;A
20:INPUT "DAY #?";B
30:INPUT "YEAR?";C
40:INPUT "LATITUDE?";D
50:INPUT "LONGITUDE?";E
60:INPUT "ZONE CORR.? "
   ;F
70:G=0: INPUT "ON DAYLI
   GHT TIME? (Y/N)";I$
80:IF I$="Y" LET G=1
90:INPUT "COORD EPOCH?
   (1950)";H
100:N= INT (275*A/9)-2*
    INT ((A+9)/12)+B-30
110:R=C/4:T=R- INT (R):
    IF T>0 GOTO 130
120:IF B>2 LET N=N+1
130:P=C-1:R= INT (P/100)
    :S=2-R+ INT (R/4):T=
    INT (365.25*P)
140:R=(S+T-693597.5)/365
    25:S=6.646+2400.051*
    R
150:O=24-S+(24*(C-1900))
160:M=(C-H)/360000:R=(H-
    1900)/100
170:K=4608.5+2.8*R:L=200
    4.7-.8*R: BEEP 1
180:"B" U=0: INPUT "RA?
    (HH.MMSS)";X
190:INPUT "DEC? (DD.MM)"
    ;Y
200:X= DEG (X)*15:Y= DEG
    (Y)
210:INPUT "TIME? (HH.MM)
    ";Z
220:Z= DEG (Z)
230:IF U=0 LET S=K+L*
    SIN (X)* TAN (Y):T=L
    * COS (X):X=X+S*M:Y=
    Y+T*M
240:T=N:P=Z-G+F
250:IF P>24 LET P=P-24:T
    =T+1
260:Q=T*.0657098-O+P*1.0
    02738
270:IF Q>24 LET Q=Q-24
280:IF Q<0 LET Q=Q+24
290:R=Q-E/15: IF R<0 LET
    R=R+24
300:S=R*15-X
310:IF S<0 LET S=S+360
320:T= SIN (Y)* SIN (D)+
    COS (Y)* COS (D)*
    COS (S):V= ASN (T)
330:U=( SIN (Y)- SIN (D)
    * SIN (V))/ COS (D)/
    COS (V):W= ACS (U)
340:P= SIN (S): IF P>0
    LET W=360-W
350:BEEP 2: PRINT USING
    "####.##";"ALT=";V;"
     AZM=";W
360:"C" INPUT "NEW OBJEC
    T? (Y/N)";I$
370:IF I$="N" LET U=1:
    GOTO 210
380:U=0: INPUT "WANT TO
    ENTER RA? (Y/N)";I$
390:IF I$="N" GOTO 410
400:GOTO "B"
410:INPUT "OBJECT #?";P
420:R=A(P+30)*E-5:S= INT
    (R)
430:X=(R-S)*E2:Y=(S*E-2)
    -100: GOTO 200
440:"D" INPUT "STARTING
     #?";S
450:S=S+30: FOR T=S TO 2
    50
460:INPUT "RA (HH.MMS) "
    ;Q
470:INPUT "DEC (DD.MM) "
    ;P
480:A(T)=(P+100)*E7+Q*E3
    :R=A(T):T=T-30
490:USING : PRINT "A(";T
    ;")=";R
500:T=T+30: NEXT T: END
```

Equatorial to Altazimuth Conversion Program

Lines 10–90: Input date and place
Lines 100–120: Compute day number
Lines 130–170: Precession routine
Lines 180–200: Input new RA and Dec
Lines 210–220: Input local time
Lines 230–350: Coordinate conversion
Lines 360–400: Source of next object
Lines 410–430: Recall from memory
Lines 440–500: Store in memory

This program will run "as is" on the Sharp 1250A and Radio Shack PC3. In the program, "A", "B", and so forth are defined subroutines. Start the program by pressing the DEF key and then the A key — do not type RUN. You can find objects either by entering their coordinates in DEF B or by storing coordinates in DEF D and recalling them in DEF C. (You must store at least one object before you can use the DEF C recall routine.) The double-strike E in lines 420, 430, and 480 denotes an exponent.

a tape recorder I can save 225 objects I've keyed in on a tape and reload the objects on the tape later. By making tapes, I can build as large a catalog as I want — a tape for spring, a tape for summer, a tape for fall, and a tape for winter. All I need in the field is a list that tells me each object's number on that tape.

Telescope Requirements

The computer, compass, and inclinometer technique will work with any Dobsonian telescope as long as the altitude and azimuth axes of the telescope are at right angles to each other. Although I'm sure most people who've built Dobsonians weren't thinking about perpendicular axes when they built their telescopes, the axes of most Dobsonians are reasonably accurate anyway.

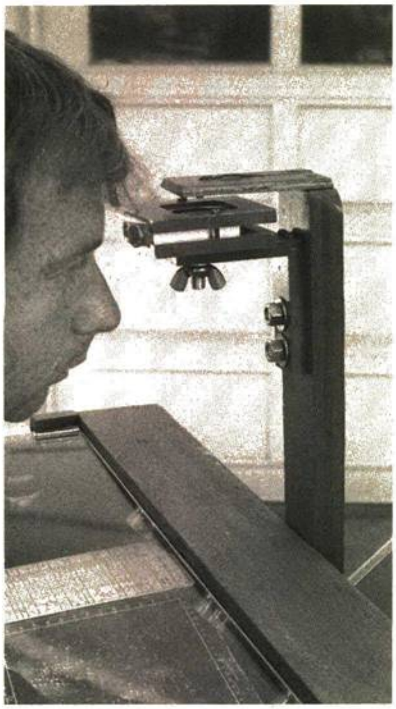
If you're building a Dobsonian for computer finding, take pains to make it precise. Make sure that the plywood is neither warped nor bowed and that the side bearings are perfectly round and exactly centered on the tube's vertical axis. Install the center bolt in the base perpendicularly and attach it permanently to the base.

You should also work out a way to level your telescope's mounting. Although you could put jacks under the feet or leveling knobs to turn, nothing I've seen works better than slipping thin wooden wedges under the feet of the ground board.

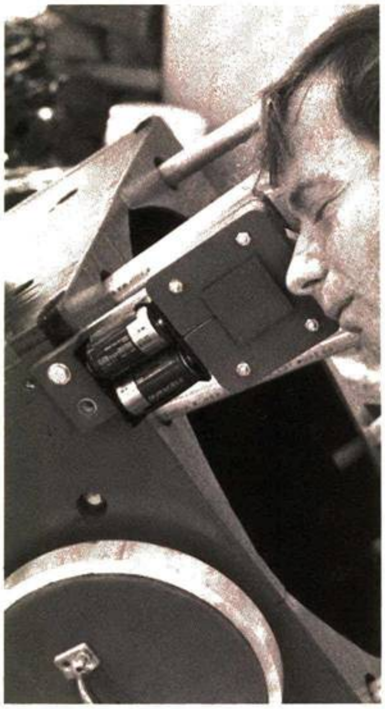
Because the compass is magnetic, your telescope must not have a magnetic field of its own, and ideally it shouldn't have any iron or steel parts. In practice, bolts and other common Dobsonian hardware don't bother the compass if they're over a foot from it. I mounted my compass and inclinometer on arms eighteen inches long; these keep the compass free of magnetic interference.

Of course the electrical field from the current that lights the LED induces a small magnetic field. Keep the current-carrying wires close together and twisted around one another to minimize their magnetic field, and check how much the compass deflects when you turn on the lamp. In my setup the deflection is less than 0.1° — too small to matter.

All the materials you use in your compass bracket must be nonferrous.



TO SET AZIMUTH, you just read the compass. A bracket on the rocker box supports the compass at a convenient height.



AN INCLINOMETER shows elevation of the telescope. For use in astronomy, add a battery-powered LED for illumination.

Wood, brass, and aluminum are fine. Iron and steel are out.

The Joy of Finding

When you set up your telescope for a night's observing, level the telescope first. I place the ground board on the ground and slip shims under its feet until a surface level shows me it's level. (Surface levels are circular levels that work just like the little bent tube in a conventional carpenter's level except that the bubble moves around under a slightly convex glass instead of in a tube. The surface is level when the bubble lies inside a ring in the center of the glass.)

I then set the rocker on the ground board and turn the rocker around to verify that it stays level through a full turn. This tells me that the axis of rotation is perpendicular to the surface of Earth. (I could check levelness of the rocker with a carpenter's level just as well, but it's just not as quick.) Finally, I put the telescope on the rocker and bolt the compass and inclinometer onto the rocker and tube.

I next initialize the computer program by punching in the date, the latitude, longitude, time zone, and daylight-saving time parameters. The program is now ready to go.

In a perfect world, if I were to compute the altitude and azimuth of a star, I could dial it in with no further adjustment. However, many small sources of error remain — the levelness of the rocker, the perpendicularity of the telescope's axes, the precise alignment of the telescope, the accuracy of the compass and inclinometer — and these I simply calibrate out.

To do this, I point the telescope at a convenient bright star. I tap in the equatorial coordinates of this calibration star, read the computed altitude and azimuth of the star, and then adjust the compass and inclinometer to the computed readings. I find the readings are usually correct to within a few degrees. For the rest of the night I'll be able to aim the telescope by setting the telescope to the computed coordinates.

Obviously you can't calibrate the telescope on a star when you set the telescope up in the daytime — or can you? Because the telescope is usually accurate to within a few degrees before it's calibrated, you'll have to search a little to find a bright calibration star. You can also use the Sun for calibration — enter its right ascension and declination from the *Astronomical Almanac*.

Observing now consists of typing in each new object's coordinates or recalling the coordinates from the computer's memory, typing in the time from your watch — remember to make about a minute's allowance for the lag between typing the time and getting to the eyepiece to look — and then dialing in the altitude-azimuth coordinates.

Finding an object takes about a minute: to punch in numbers, read the altitude and azimuth, and walk around the telescope and set the ladder in place to reach the eyepiece. I'm sure two observers working together could find objects a lot faster, but I'm pretty happy with this pace.

How Good Is It?

During the course of observing, keep track of finding errors. When I'm working on a fairly small section of the sky (within 30° to 45°), I've come to expect that I will find every object in the field of view at 120x on the first try. When an object isn't in the field, it will lie just outside the field. At 60x my digital setting circles never miss.

However, when I swing the telescope 90° or more from my original calibration region, I expect to see errors of a half-degree cropping up, because of the residual mechanical error in the telescope mounting. To correct for this, I recalibrate the compass and inclinometer for the new region of sky and go on observing.

If you try computer-aided finding and you find significantly larger errors, chances are your telescope's altitude motion isn't perpendicular to the azimuth motion. Minor adjustments on the position of the side bearings will probably cure the problem.

One final note on accuracy: After midnight you must restart the program and enter the new date in the computer's memory. If you don't, all your pointings will be about a degree off because the computer will be telling you where the objects you want to find were the night before.

As you may have guessed, I believe setting circles will revolutionize the use of large telescopes and small telescopes alike. For an outlay of $200 to $250, you can find objects as quickly, efficiently, and accurately with a Dobsonian as you could with the same telescope on an equatorial mounting with setting circles.

This technique works as well on my club's 20-inch telescope as it does on my rich-field telescope. There's no need to fuss around wondering which 8th-magnitude star corresponds to which dot on the star chart, because the object you're looking for is already in the field of view.

Why wait? Everything you need can be purchased for the cost of a couple eyepieces. Computerize your Dobsonian telescope and make observing the thrill you always wanted it to be. ☐

Bill Burton has demonstrated computer-aided finding on his 17.5-inch and his club's 20-inch Dobsonian telescopes at Stellafane and AstroFest. The author would like to acknowledge the help of Robert Bunge, Jay Elkes, and John Kerns with this article and the computer program.

Ten Pointers for Mars Observers

1 Observe from a level, grassy site away from concrete and asphalt surfaces and buildings.

To see the minute surface details of Mars, you need to avoid surfaces that give off warm air currents, which blur planetary detail. Concrete and asphalt surfaces, rocky and sandy soil, and buildings heat up during the day and often don't cool down until many hours after sunset. As they cool, they heat the air above them, and these rising currents of warm air disturb the rays of light that reach your telescope.

The result is images that "swim" or "boil" in the telescope's eyepiece. The ground surface least likely to heat the air — and thus afford you the best views of Mars — is an open, grassy surface.

2 Allow your telescope ample time to cool down to the outside temperature.

Earth's atmosphere isn't the only cause of poor images. Warm air escaping from your telescope can also blur your view. Let your telescope cool to the air temperature by taking your telescope outside an hour or two before you plan to observe.

3 Make sure your telescope is accurately collimated.

Your telescope's optics must be precisely aligned, or you will have trouble observing detail. If you have a Newtonian reflector — especially if you must remove the mirror from the mounting for transportation — make sure the primary and secondary mirrors are accurately aligned. A Schmidt-Cassegrain telescope allows you to adjust the secondary mirror to achieve alignment. You may not have to worry about collimation if you have a refractor, because these systems are typically sealed with the optics semipermanently aligned. For specific information on collimating, see your telescope manual or "Collimating Your Telescope" by Robert Burnham and Richard Berry, January 1981.

4 Use an off-axis stop-down mask to enhance the image of Mars in large-aperture Newtonians.

If your 17.5-inch reflector doesn't provide a view of Mars as pleasing as that in your friend's 4-inch refractor, an off-axis stop-down mask might fix the problem. A mask can improve a poor image by stopping light from reaching less than perfect zones of the mirror. (These optical defects don't matter in low-power viewing.)

To make this type of mask for a 17.5-inch scope, use a piece of heavy cardboard large enough to cover the open front end of your telescope. Cut a circular hole about 6 inches in diameter between the center of the telescope (where the diagonal is in the tube) and the edge. Place the mask over the end of the tube whenever you want to observe at high magnification.

5 Use the lowest magnification that shows all the detail on the planet's disk.

Don't be afraid to experiment with different magnifications. Start by finding Mars at low power, and then switch to something like 150x. The view should be crisp and will provide enough magnification to see a lot of detail. Then try a variety of eyepieces to see which is most pleasing. When you reach the point where the image sharpness starts to decline, back off and use a lower-power eyepiece.

Too much magnification makes images blurry and indistinct. While magnification is necessary to see details on a planet's surface, it can't be increased forever. Use the lowest possible magnification that shows all of the detail on the planet's disk.

6 Begin sketching Mars early in the apparition to sharpen your observing eye.

Sketching is the easiest, cheapest, and most effective way to record what you see. All you need is a notebook with clean, white paper; a compass or circle template; and a pencil.

Use a 42-millimeter-diameter circle to represent the disk of Mars. Draw in the dark terminator (if it's visible), and then rough in the outlines of the polar caps and dark markings. Use the pencil sparingly as you darken the outlined areas and add any small details that you see. Finally, record all pertinent information: time, date, telescope, magnification, filters, and seeing conditions. For more tips on sketching Mars, see "1988: A Great Year for Mars" by Jeff Beish and Donald C. Parker, March 1988.

7 Don't hurry: You need at least half an hour to see and sketch all the detail on the disk.

You can't absorb all there is to see in a quick look.

Take at least half an hour to sketch the planet and its surface features. During this time, moments of better seeing will come and go, each offering brief glimpses of more detail. Keep working on a sketch until you feel it records all there is to see.

Give yourself a break too. Occasionally walk around and stretch your arms and legs — get that blood flowing again! When you return to the eyepiece, you'll be more refreshed and ready to observe again.

8 **Improve image contrast with color filters.** Color filters, either dyed glass or gelatin, will help you see subtle details on the surface of Mars. Orange filters increase the contrast between light and dark features on the surface and help show yellowish dust clouds. Red filters provide the maximum contrast for surface features and also reveal some dust clouds. Yellow filters brighten Martian deserts, and green, blue, and blue-green filters darken the deserts while brightening features in the atmosphere. Violet filters reveal haze along the limb and various cloud features.

9 **Share Mars with your family and friends.** Give your family and friends a little background information on the planet first: Mars' size, distance, and how it differs from Earth. Then explain that this autumn is the best time to see Mars since 1971 — and that they won't get a view this good for another seventeen years. But know when to stop. If someone reaches his limit, don't bore him with a lecture!

10 **Send copies of your sketches and photos to the Association of Lunar and Planetary Observers.**

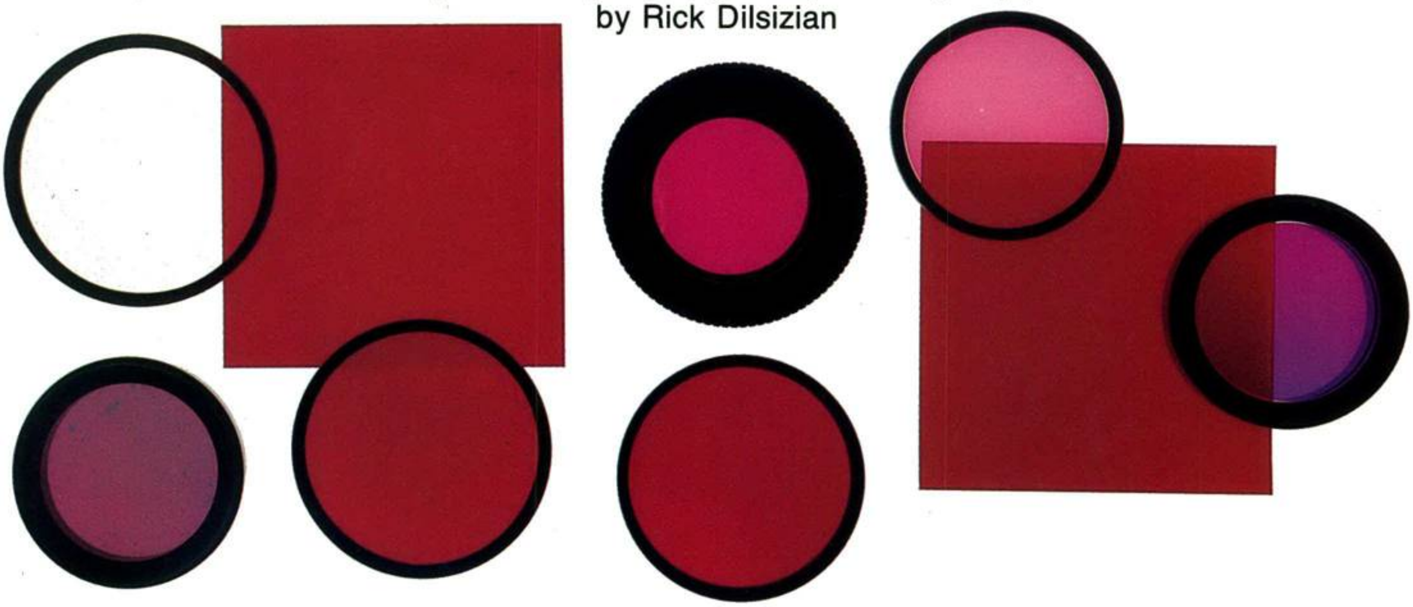
Backyard astronomers who draw and photograph Mars this year can contribute to the study of Mars.

The Association of Lunar and Planetary Observers (ALPO), a group of amateur astronomers studying the solar system, is collecting material on Mars to help professional astronomers. If you would like your observations or photographs included in ALPO's archives, write to: Mars Recorders, Box 97-0469, Miami, FL 33197. Enclose a self-addressed, stamped envelope with your letter. Your observations will become part of a legacy useful long after this "year of the Red Planet." ☐

Filters for Better Astrophotos

With the right combination of filters and film you can enhance faint nebulosity and sharpen images in your deep-sky photos.

by Rick Dilsizian



Deep-sky astrophotographers probably suffer more from light pollution than other amateur astronomers do. From most urban and suburban sites, photographs of deep-sky objects become fogged with unwanted sky light long before any faint nebulosity is recorded on the film.

The effects of manmade lighting are often severe, but there are ways to combat the problem. Astronomical filters can partially block light pollution from reaching the film, which gives astrophotographers in less than ideal locations some of the advantages of a darker site.

Other types of astronomical filters not only block undesirable light but transmit the specific wavelengths of light emitted by deep-sky objects. And still other filters counteract the effects of chromatic aberration that cause stellar images to appear disproportionately large and fuzzy.

The quality of your deep-sky images depends on several factors, but a fundamental constraint on the image quality is the amount and nature of the light recorded on film. You want to record the light emitted by deep-sky objects and at the same time eliminate extraneous light. By choosing filters that transmit the desirable light and reflect the undesirable light, you can control the relative contributions from these sources. And by using films sensitive to the desirable light, you can ensure that your photos will capture all the light you want.

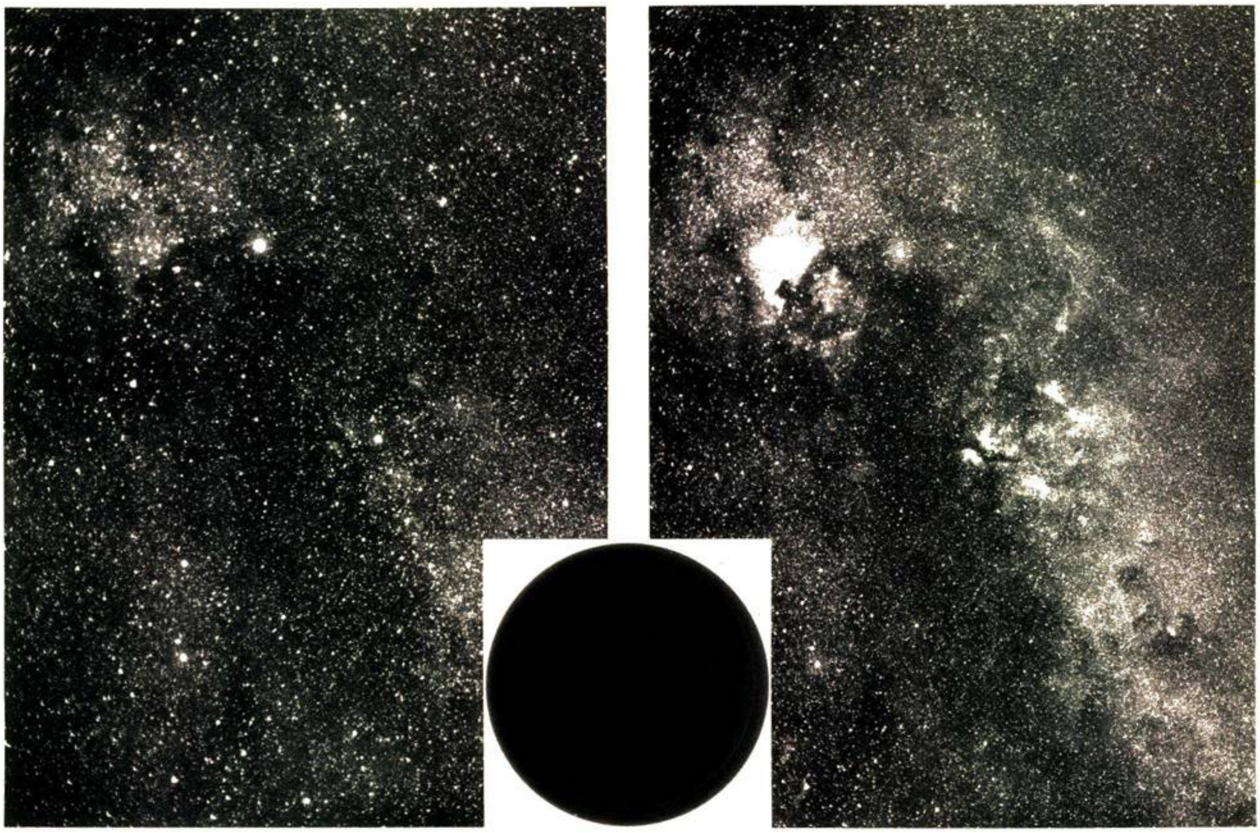
I want to concentrate on how to use filters in piggyback astrophotography — a camera and lens ride on top of a telescope used to guide the photograph — although filters work equally well in through-the-telescope photography. The filter can be placed in one of two positions: in front of the lens so the light passing through the lens is what you want to capture on film, or between the lens and the camera so all the light passes through the lens and is filtered before it reaches the camera's film plane. The first method is the most common.

Lines from Outer Space

The light we want to photograph and the light we want to suppress are both part of the visible spectrum that comprises all the colors humans can see. These colors depend on the wavelength of the light. From the longest wavelength to the shortest the major colors of the visible spectrum are red, orange, yellow, green, blue, and violet. Wavelengths longer than red are infrared and those shorter than violet are ultraviolet.

Within the visible spectrum there are many distinct wavelengths of light that stars, galaxies, and nebulae emit because of the nature of the chemical elements that make up these objects. Think of each element as a radio station: each transmits its own "programs" and each program is on a separate wavelength of light. The wavelengths of light are often expressed in angstroms, where 1 angstrom equals 0.0000000001 meter. Visible light spans from about 4000 angstroms in the violet to 7000 angstroms in the red.

Each element broadcasts a unique set of specific wavelengths of light that we want to capture on film. But light from celestial objects doesn't reach your lens unaccompanied. It is overlaid with a haze of manmade light — particularly emission from sodium and mercury vapor street lights. We need to block this manmade light while letting through the light of the deep-sky object.



INCREASED RESOLUTION AND CONTRAST are two benefits an H-alpha filter provides. A 5-minute unfiltered photo of the Cygnus region (left) records bloated star images compared with a 40-minute exposure made through an H-alpha filter (right).

The first thing we must do is identify the spectral lines emitted by the deep-sky objects we want to capture on film. In gaseous emission nebulae the primary lines are from the most common element in the universe, hydrogen. Stars illuminate vast clouds of hydrogen through a process called fluorescence, which transforms invisible ultraviolet radiation into visible light. The primary line of hydrogen emission is in the red end of the spectrum at 6563 angstroms and is known as the H-alpha line. The second strongest line is H-beta in the blue end of the spectrum at 4861 angstroms.

Although hydrogen is the dominant element in emission nebulae, other elements contribute significantly to a nebula's visible light output. In particular, oxygen and nitrogen produce four "forbidden" lines of radiation — forbidden because they only occur in the extreme low-density environment of interstellar space and never in laboratories on Earth. Oxygen atoms that have lost two electrons emit green light at 4959 and 5007 angstroms, and singly ionized nitrogen produces two red lines at 6548 and 6584 angstroms.

Other deep-sky objects have different colors. The color of a galaxy or star cluster depends largely on the average color of the stars that make up the object. Most elliptical galaxies and globular clusters appear yellow because they consist mostly of old, cool stars. Spiral and irregular galaxies and open clusters are dominated by hotter, younger stars and thus appear bluer. Planetary nebulae have spectra similar to emission nebulae, though the relative contributions of the forbidden oxygen and nitrogen lines are greater.

Along with the wavelengths of light we want to record, there are certain wavelengths of light we want to prevent from reaching the film. The most damaging light comes from mercury and sodium vapor lights. The primary emission lines of mercury occur at 4047 and 4358 angstroms in the blue, at 5461 angstroms in the green, and at 5790 angstroms in the yellow. Sodium emits two strong lines in the yellow region of the spectrum at 5890 and 5896 angstroms.

The final source of light we want to reject is airglow — the faint light emitted by atoms and molecules in Earth's atmosphere. Airglow results principally from three lines of ionized oxygen at 5577, 6300, and 6360 angstroms.

Finding the Right Filters

A key factor in determining how well your deep-sky astrophotographs turn out is how much of the nebular light and how little of the "polluted" light reaches the film. Filters let you control this factor.

Astrophotographic filters fall into two general categories: filters that transmit all light past a certain wavelength and those that transmit only certain wavelengths within the visible spectrum. Because manmade lighting produces emissions at wavelengths of 5896 angstroms and shorter, we are interested only in filters of the first type that transmit all light longer than this wavelength and none at or below it. These are red filters. Filters of the second type are more selective and are commonly known as LPR, or light pollution rejection filters.

Filters are made either of glass or gelatin. Glass filters are durable but more expensive than gelatin filters. Commercially made glass filters do an extremely effective job in providing superior images for astrophotography. They are more resistant to scratching, relatively inexpensive, and not as susceptible to fingerprint damage as gelatin filters.

Gelatin filters are used in their own filter holders or in more specialized applications such as astrophotography with Schmidt cameras. Gelatin filters are cheaper than glass filters and come in a wider variety of spectral characteristics. Kodak, a prime manufacturer of these filters for seventy-five years, has adopted a standardized numbering system for filters based on the wavelengths transmitted by each filter.

Red Filters

Red filters isolate the prominent H-alpha line at 6563 angstroms in emission nebulae such as the North America, the Lagoon, and the Rosette. These filters increase the contrast between an emission nebula and the background sky because they transmit the red part of the nebular radiation while suppressing the generally blue, green, and yellow light from manmade sources.

The most useful gel filters are Wratten #25, #29, and #92 filters, which begin transmitting light above 5800, 6000, and 6200 angstroms, respectively. Of the three, a #92 is best for deep-sky astrophotography because it transmits the least unwanted light. The #29 filter prevents only 26.5 percent of the airglow oxygen emission from passing through, compared to the 82.6 percent the #92 filter blocks. A #25 filter is not as useful, because it even transmits some of the sodium vapor lines!

Two kinds of glass filter that transmit red light are commercially available. The first is known as the A filter and corresponds to the #25 gel filter. The second type of red filter is the H-alpha filter, which has become popular in the past five years. The H-alpha filter blocks light with a wavelength shorter than 6300 angstroms and transmits only about 3 percent of the airglow oxygen line at that wavelength.

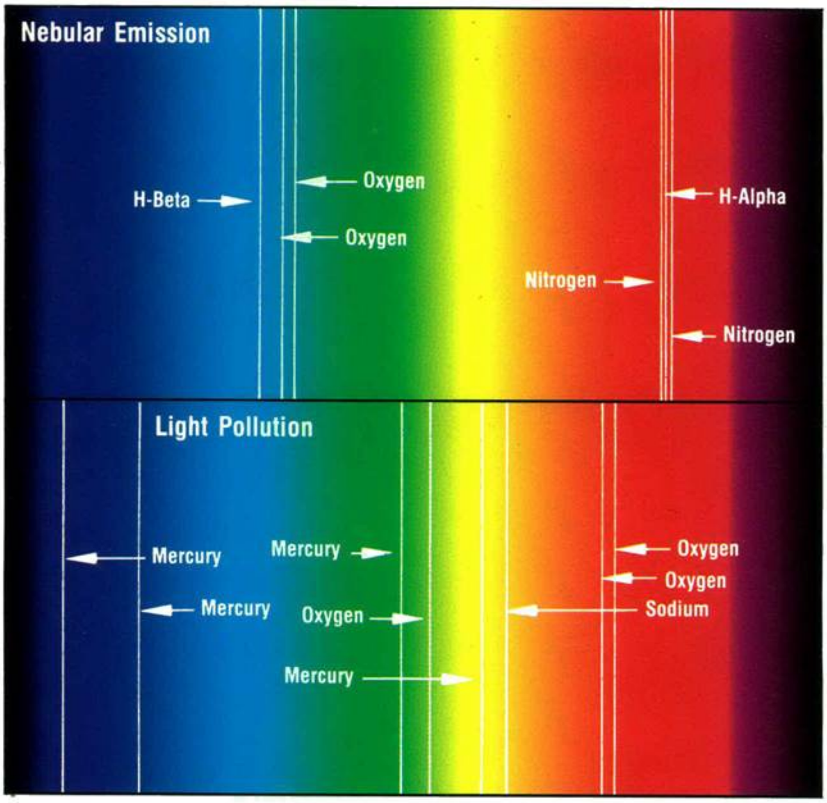
Look at the quality, resolution, and contrast in the Cygnus region photos on page 79. (Note that all the comparison photos in this article are unretouched and unaltered — they truly reflect the enhancement you can expect from filters. Each photo pair was taken on the same roll of film, on the same night (about forty minutes apart on average), with the same optical system, and was processed at the same time in the same photo chemicals.) Not only has the contrast increased between the "before" and "after" photographs but the quality of the picture is noticeably better.

This is the result of eliminating chromatic aberration — where different wavelengths of light come to a focus at slightly different locations. In the unfiltered photo, light of only one wavelength arrived at the film plane in focus; light at other wavelengths arrived at the film plane a little out of focus and blurred the images slightly. In the H-alpha photo only one color of light — red — arrived at the film plane and the aberration disappeared. The net result is a sharper, crisper photo.

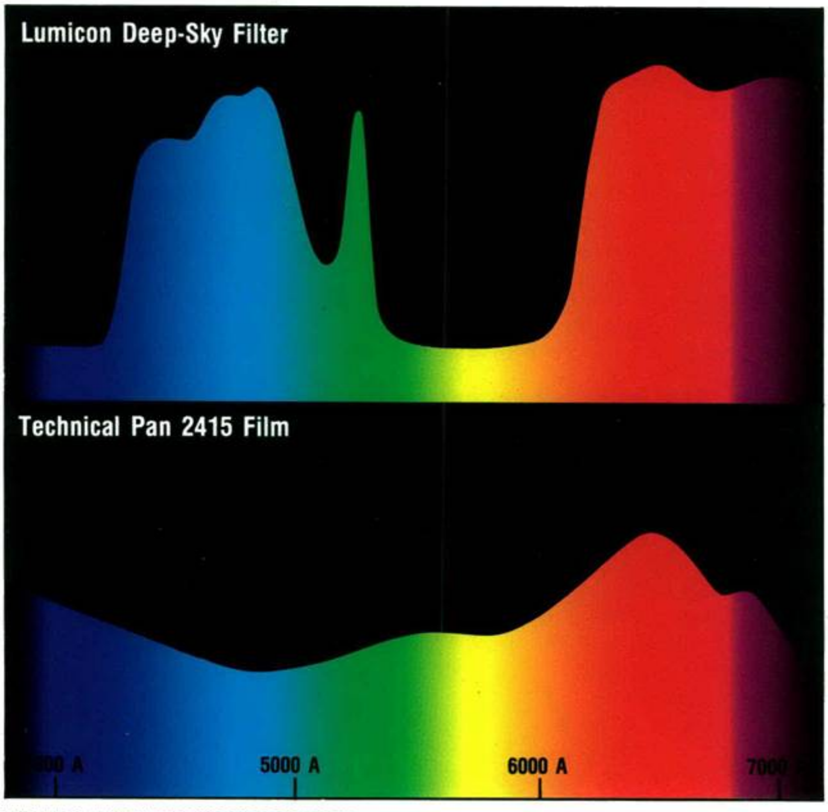
Chromatic aberration can degrade any astrophoto in which the light passes through a glass lens (as with the piggyback method). Photos taken at the prime focus of a reflecting telescope do not suffer from the problem.

Red filters have two distinct disadvantages in astrophotography. First, because red filters substantially reduce

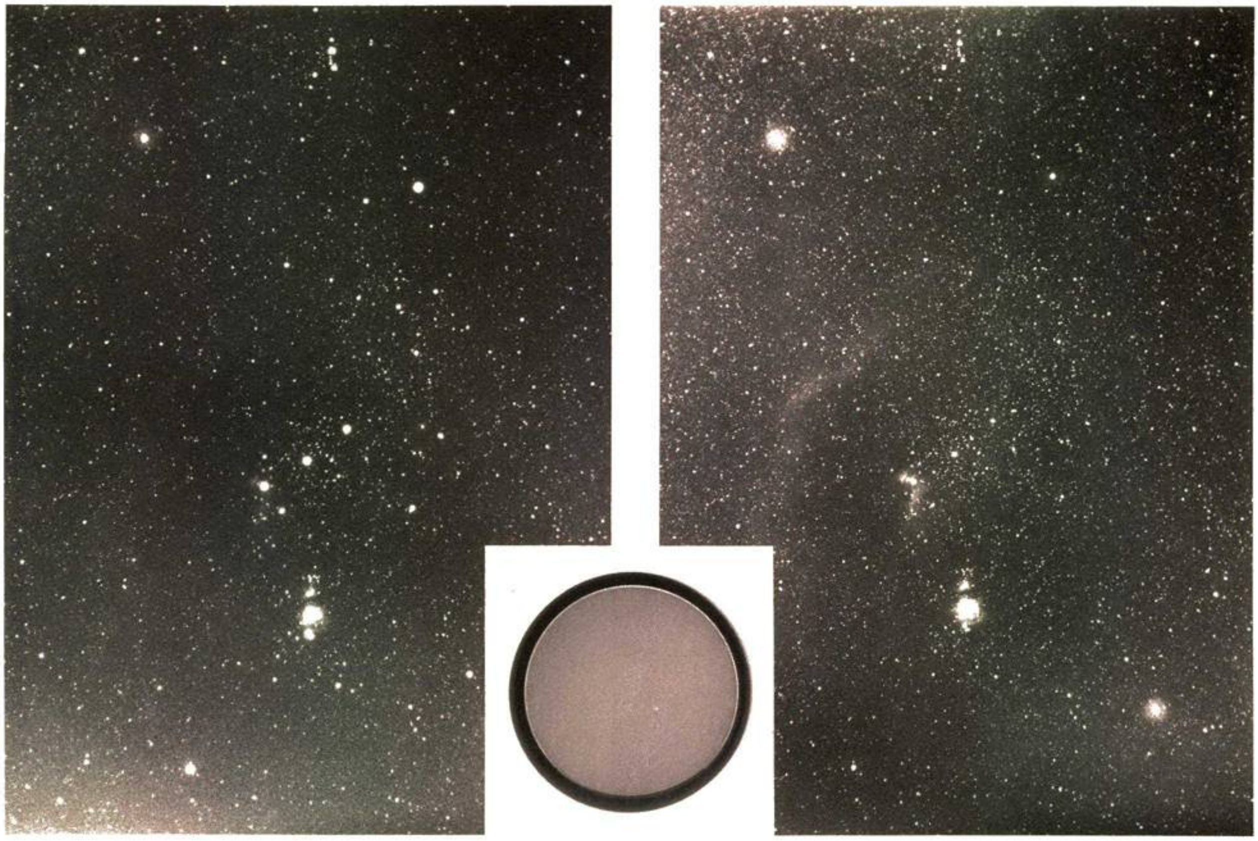
In with the Good Light and Out with the Bad



HIGH-QUALITY ASTROPHOTOS result when filters separate the "good light" emitted by hydrogen, oxygen, and nitrogen in nebulae (top) from the unwanted light of natural and manmade light pollution (above).



FILTERS AND FILM WORK TOGETHER to record nebulae. The right filter transmits nebular emission and blocks light pollution, but the film must "see" all colors transmitted by the filter, including H-alpha.



ENHANCED NEBULOSITY appears in photos taken through an LPR filter. A 5-minute unfiltered exposure of Orion (left) reveals the Orion Nebula, but a 15-minute exposure using an LPR filter (right) shows the Horsehead Nebula and Barnard's Loop as well.

the amount of light reaching the film, exposure times must be increased. A typical H-alpha photo will run three to five times longer than an unfiltered exposure.

Second, because only red light is transmitted, the focus will shift. To measure how much the focus shifts, you need to take a series of five test exposures. Center a bright star, preferably one of 1st magnitude, in the camera's view finder, then thread the filter to the front end of the lens. Next, adjust the lens f/ratio so it is "wide open" (the smallest number corresponds to the maximum aperture).

The first exposure should run 3 minutes with the distance scale of the lens set to infinity (it looks like a sideways figure "8"). Follow this with equal exposures at one quarter of the way, halfway, and three quarters of the way between this "normal" infinity setting and the "infrared" infinity setting marked by the red dot on the distance scale of your lens. Take the final test exposure at that red dot. Record each setting and exposure time on a piece of paper.

Develop the film and examine the star's image under a magnifier to see which of the five is smallest and therefore focused best. Then look up the focus setting you used: this is the distance setting you will always use with this particular lens and filter. In most cases the setting is approximately 60 percent of the distance from the normal to infrared infinity. Every lens and filter combination must be tested separately because the distance scale for each may differ slightly.

Other Useful Filters

An alternate way to reduce chromatic aberration is with a filter that blocks short wavelength radiation. All films are sensitive to ultraviolet and blue light, and at these wavelengths chromatic aberration is usually worst.

Minus-violet filters are designed specifically to transmit all light with wavelengths longer than 4400 angstroms and to block all light in the violet and near-ultraviolet portion of the spectrum. Astrophotos taken with a minus-violet filter require little increase in exposure time, though a slight shift in focus does occur. And because the minus-violet filter cuts off only the near-ultraviolet and violet end of the spectrum, it is still good for color as well as black-and-white astrophotography.

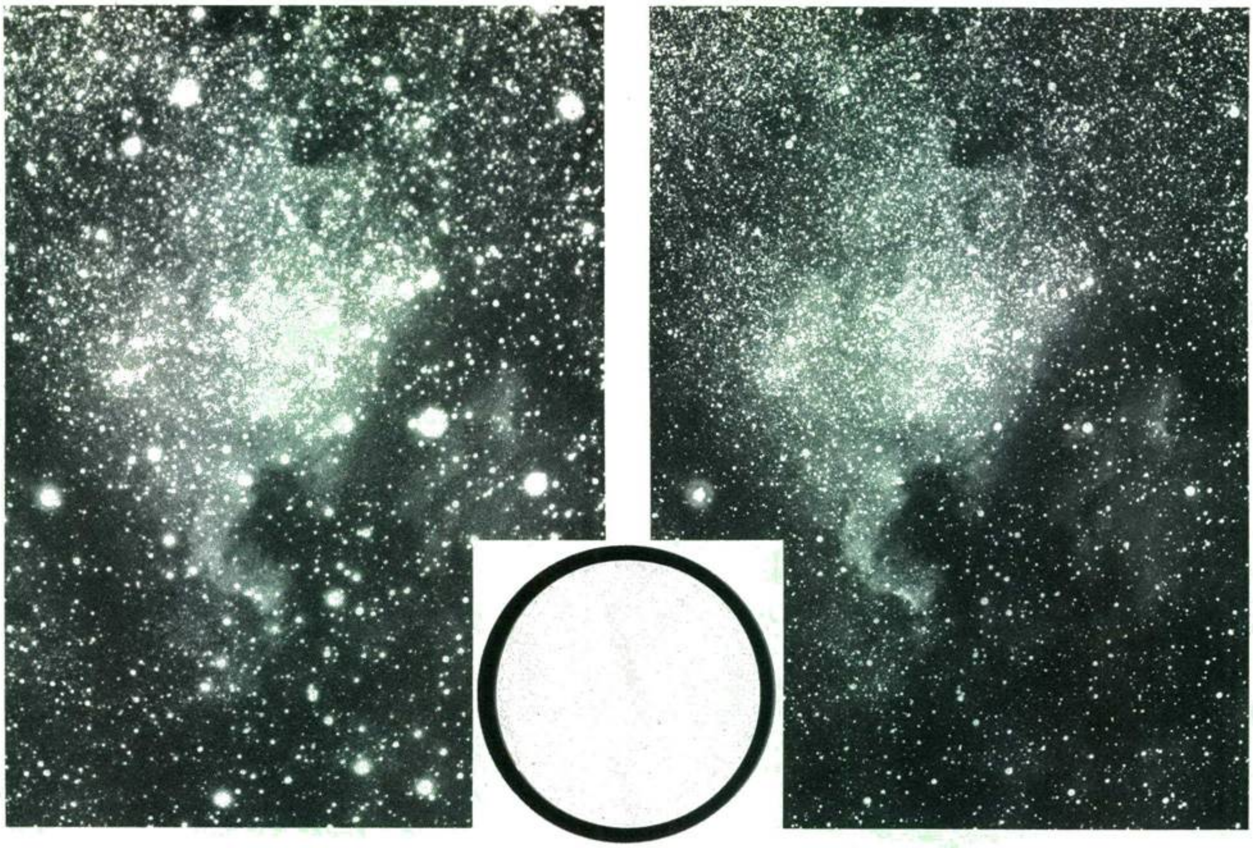
The comparison photos of the North America Nebula on page 82 show the dramatic increase in image quality when chromatic aberration is reduced. The bloated, fuzzy star images on the unfiltered photo have been replaced by crisp images that do not detract from the nebula. Contrast has not been increased: only chromatic aberration has been reduced.

Light-pollution rejection (LPR) filters transmit light across the entire range of the visible spectrum while blocking certain unwanted lines from natural and manmade light pollution. Because these filters transmit selected wavelengths across the spectrum, they are especially good for color astrophotography. Red filters, in contrast, are good only for black-and-white astrophotography.

In the photographs of Orion above, notice how Barnard's Loop (the large arc of emission along the left side of the photo) and the Horsehead Nebula just below the leftmost star in the belt of Orion stand out clearly in the filtered photo but are difficult to nearly impossible to see in the unfiltered photo. Although an H-alpha filter would bring out these regions even more dramatically, the exposure would need to be about twice as long as that for the LPR filter photograph.

Film Sensitivity

The final piece of the deep-sky-photography puzzle is the film. We have seen that there are both desirable and undesirable emission lines, and different filters will transmit or block different amounts of these lines. But the light you want to capture will be recorded *only* if the film is sensitive at those wavelengths. There is no advantage in using a red filter if the film can't



CRISP STELLAR IMAGES result when chromatic aberration is reduced. The bloated star images in a 10-minute unfiltered photo of the North America Nebula (left) disappear in a 12-minute photo taken through a minus-violet filter (right).

record red light or records it only weakly. Remember that it is the combination of film *and* filter that produces the special "window" in the spectrum through which the final photo will be taken.

Black-and-white films are called "orthochromatic" if they are sensitive only to ultraviolet, blue, and green light and "panchromatic" if they are sensitive from the ultraviolet through the red region of the spectrum. The word panchromatic implies that the film is sensitive throughout the entire visible spectrum, but for astrophotography in particular this is not true.

Films that are panchromatic drop sharply in spectral sensitivity between 6400 and 6500 angstroms. Because the most prominent line in emission nebulae is H-alpha at 6563 angstroms, panchromatic films such as Plus-X, Tri-X, TMax 100, and TMax 400 are poor choices for capturing the full extent of such nebulae. For galaxies and other deep-sky objects that are not as prominent in the red, panchromatic films work well.

The best type of black-and-white film for deep-sky photography is a panchromatic film with extended red sensitivity. These films are sensitive to radiation past 7000 angstroms and can easily record H-alpha emission. Kodak Technical Pan 2415 is the most commonly available example of this type of film.

Most color films, on the other hand, are sensitive to blue, green, and red light and are therefore good at capturing the entire range of colors in astronomical objects.

Putting It All Together

A good target for your first filtered deep-sky photograph is the constellation Orion. With an H-alpha filter and a normal 50mm lens you can record many of Orion's spectacular sights. Orion fairly brims with hot, ionized hydrogen gas — especially in the regions around the Orion Nebula, the Horsehead Nebula, and Barnard's Loop — that will show up dramatically in a long exposure photograph.

A good photo store will have or can order the typical red filter (#25) and the Wratten filters #29 and #92. But there are also several suppliers of the specialized filters used in astronomical photography. Among these are Lumicon, Celestron, Orion Telescope Center, Adorama, Daystar, Morvac Optical Coating, Sky Scientific, and VERNONscope.

H-alpha and minus-violet filters are fairly inexpensive, averaging between $30 and $50 apiece. LPR filters are more expensive because they are more difficult to manufacture. Expect to pay between $60 and $300 based primarily on the filter's size. The larger the size of the filter, the greater the price.

Glass filters come in different sizes because they have to thread onto the front end of a camera lens. Consult either the camera manual or lens brochure to determine the correct size for your lens; it is commonly referred to as the "screw size" or "thread size." The size is usually printed on the inside of the lens cap supplied with the lens. You will need to supply this information when ordering your filter. (Make sure you don't confuse the thread size with the lens focal length!)

With H-alpha filter in hand, you're ready to plan that photo of Orion. Your first consideration should be the film. The best black-and-white film is gas-hypersensitized Kodak Technical Pan 2415. This film is particularly sensitive to red light and will capture the H-alpha emission line. Gas-hypersensitized means the film has been "soaked" in a gas to boost its sensitivity. Hypersensitizing film is like giving it a vitamin shot in the arm — it doesn't slow down as rapidly during long exposures on faint objects. Kodak Technical Pan 2415 is also a high-resolution, extremely fine-grained film that produces exceptionally good images.

Determining the appropriate exposure time is the next major consideration. I have found that with a minus-violet filter I need to increase the exposure 1.1 times the exposure without the filter, with an LPR filter I increase the exposure to 1.5 times the unfiltered value, and with an H-alpha filter I increase the exposure time to 3 times the unfiltered exposure. For the Wratten #25, #29, and #92 filters the exposure time increases from two to four times the unfiltered value.

For example, a 10-minute unfiltered exposure should be increased to 11 minutes (10 x 1.1) with a minus-violet filter, to 15 minutes (10 x 1.5) with a LPR filter, and to 30 minutes (10 x 3) with an H-alpha filter, to get the same image density on the resulting negative or slide.

For our photo of Orion with an H-alpha filter on gas-hypersensitized Technical Pan 2415 film, the exposure time also depends on the f/ratio of the lens. At f/1.4 expose for 10 to 20 minutes, at f/2 for 20 to 40 minutes, at f/2.8 for 40 to 60 minutes, at f/4 for 60 to 100 minutes, and at f/5.6 for at least 100 minutes.

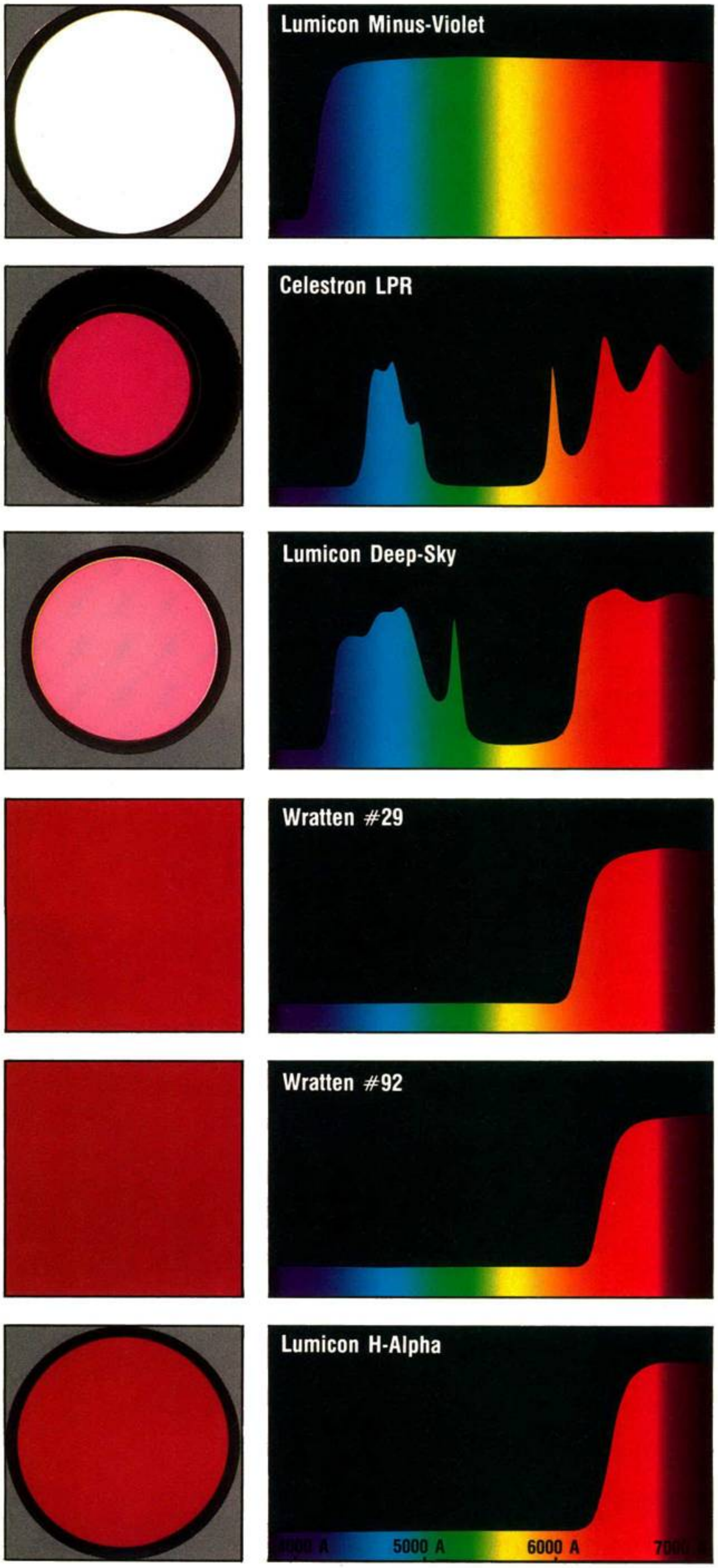
Now that we have ascertained both the film and the exposure time for the photo, let's put it all in practice. First find the proper focus for the lens by examining the images obtained at the five different distance settings between normal and infrared infinity as explained before.

Taking the actual exposure of Orion is as simple as taking the test exposures that determined the position of best focus. Compose the entire constellation in your camera's view finder, and then attach the H-alpha filter to the front end. (It's very difficult to see the constellation with the filter already on.) Next set the lens aperture wide open (usually f/1.4, f/1.8 or f/2 for a normal 50 mm lens), check the distance setting that you found earlier, set the camera shutter speed to B or T for a time exposure, and take the photo for the required time. (Check your camera manual to see if long exposures will drain the battery — there may be a manual override.)

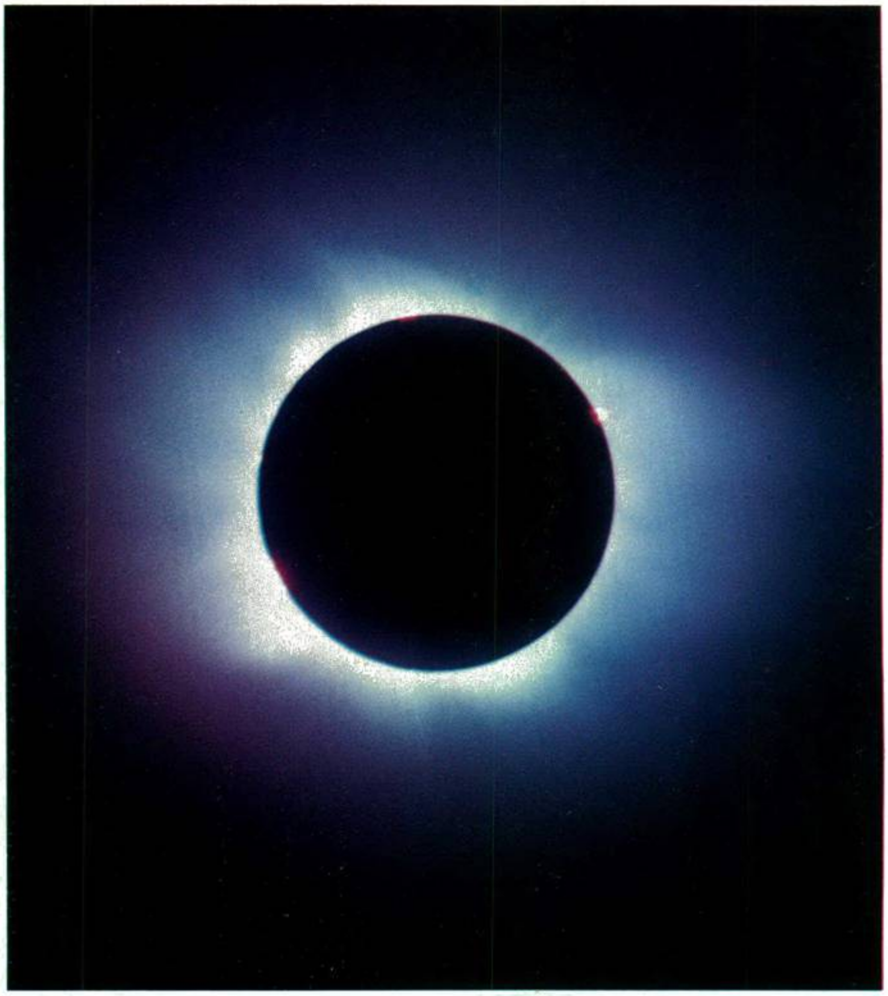
By eliminating unwanted spectral lines from light pollution and emphasizing the strong emission lines generated in astronomical objects, filters are an effective way to take high-quality deep-sky astrophotographs. Filters are inexpensive, readily available, and easy to use — and they offer hope to frustrated astrophotographers stuck in urban and suburban environments. Although nothing can beat a good dark-sky site, you can simulate a darker sky right in your own backyard with the right filter. ☐

Rick Dilsizian is an assistant professor of mathematics and computer science at Westchester Community College in Valhalla, New York. His most recent article in ASTRONOMY, "High-Resolution Lunar and Planetary Photography," appeared in the January 1988 issue.

Filter Transmission Curves



SOLAR ECLIPSE SHOWS MAGNIFICENT PROMINENCES



MARCH 18'S SOLAR ECLIPSE offered observers a two- to four-minute view of the Sun's corona and a pair of spectacular prominences.

A total eclipse of the Sun thrilled observers on land and at sea in the Pacific on March 17-18, 1988. The eclipse began at 23h24m UT on March 17, and ended at 4h32m UT on March 18. The path of totality extended from the Indian Ocean west of Sumatra to Indonesia and the Philippines eastward all the way to a point in the Pacific south of Alaska. Observers scattered across this line used filters, cameras, and telescopes to glimpse two to four minutes of totality, depending on their location.

Glenn Schneider of Baltimore watched the eclipse from Bangka Island, Indonesia, about 875 yards south of the eclipse center line. Schneider wrote that the event started without excitement but blossomed into a great show. "Due to a large cumulus cloud hugging the eastern horizon and growing with the morning sunlight, neither sunrise nor first contact was visible. The Sun broke free from the clouds approximately thirty minutes after first contact. Cirrus and cirrostratus clouds lay scattered across the sky.

"As I counted down toward totality, the cries and shouts of observers around me rose in intensity. At second contact a dazzling diamond ring sprang forth and I photographed it several times. I then glanced through a 4-inch refractor and was astounded by the sight of the most magnificent prominences I have ever seen during an eclipse. A large loop prominence with a small, jetlike protrusion was visible arcing above a dark bubble in the inner corona. Diametrically across the solar disk was a huge hedgerow prominence like one visible during the February 1979 eclipse. Smaller prominences dotted the solar limb. Looking skyward with the naked eye, I was amazed to see the two large prominences."

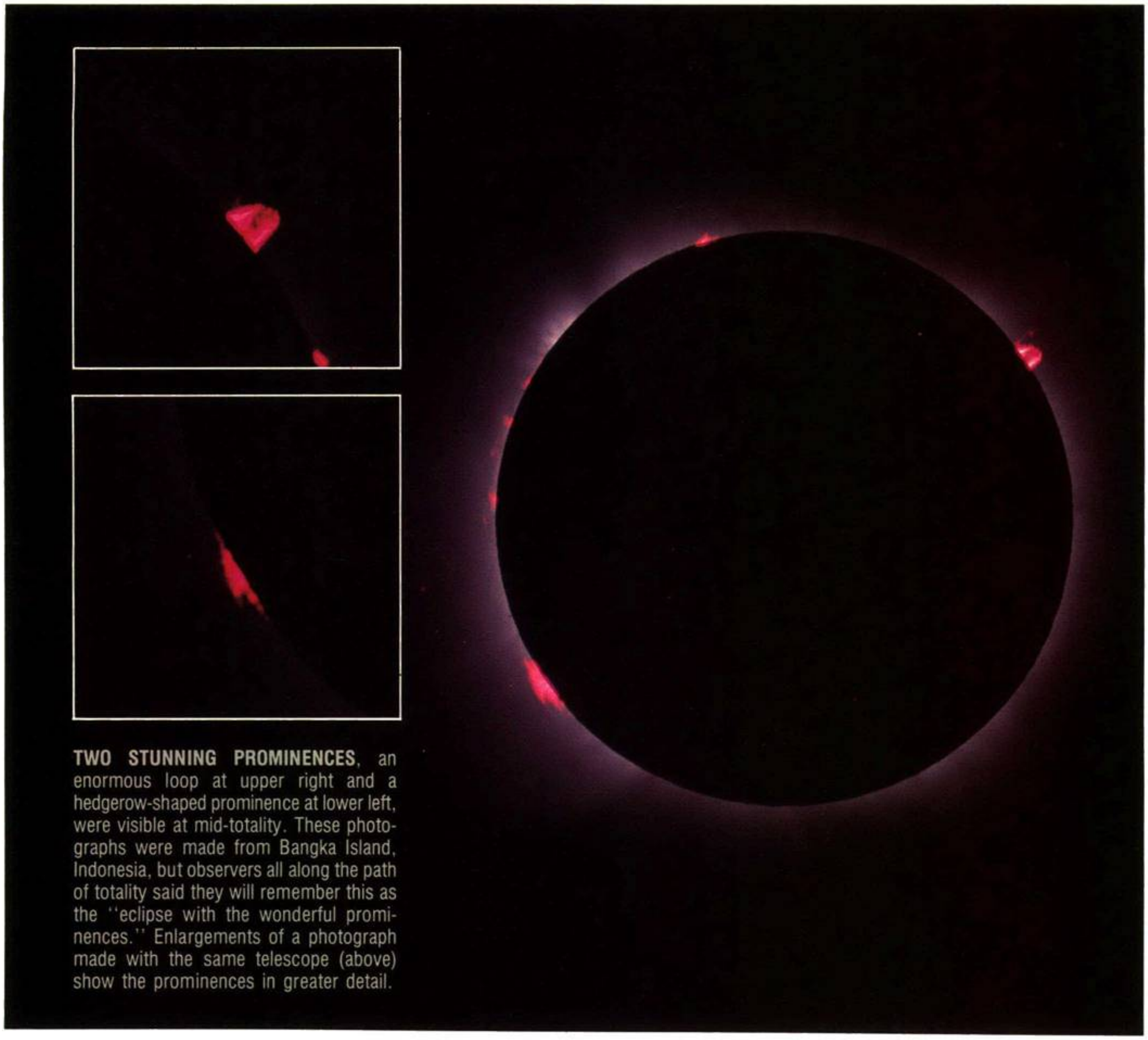
Near the city of General Santos in the Philippines, Timothy Shelton observed the eclipse with a group from the Toronto Centre of the Royal Astronomical Society of Canada. "About twelve minutes before second contact a large cloud obscured the Sun. A break in the clouds followed, but then another cloud bank rolled in. Nevertheless, we were lucky. We viewed the eclipse without cloud interference except for the last minute.

"This was the darkest eclipse I can remember: I was not able to read the shutter dial on my camera. The corona extended at least two solar diameters and resembled two stubby wings with feathers. There were quite a few prominences visible, especially after second contact. Most impressive were two large prominences diametrically opposite each other."

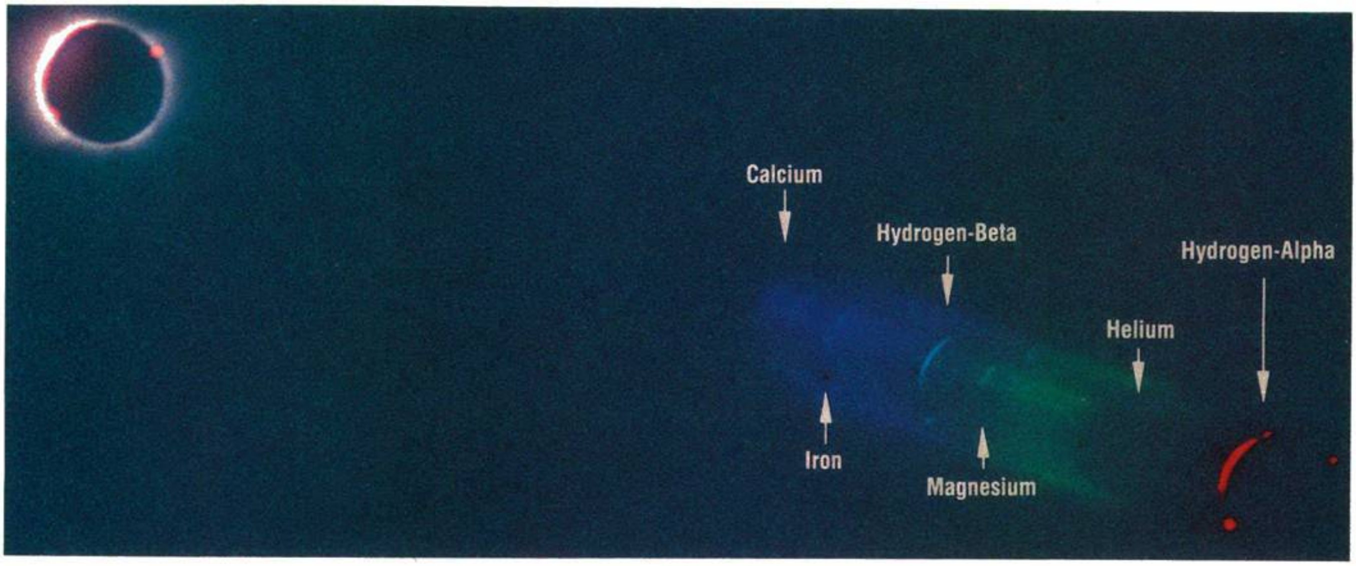
Randy Attwood of Toronto observed the eclipse with Shelton. Along with Robert May and Betty Robinson, Attwood photographed the eclipse with an 8-inch Schmidt-Cassegrain and a 5-inch refractor. He also afocally coupled a Sony CCD-V5 video camera to a 60mm refractor to produce a ten-minute videotape of the event. The tape shows several minutes of the eclipse before totality and records the building excitement from observers before showing totality.

Attwood wrote, "About one minute before totality, shadow bands became visible." Shadow bands are mottled patterns of light and shadow visible on the ground and probably caused by atmospheric refraction. "They were faint, widely spaced shadows moving northeast-southwest.

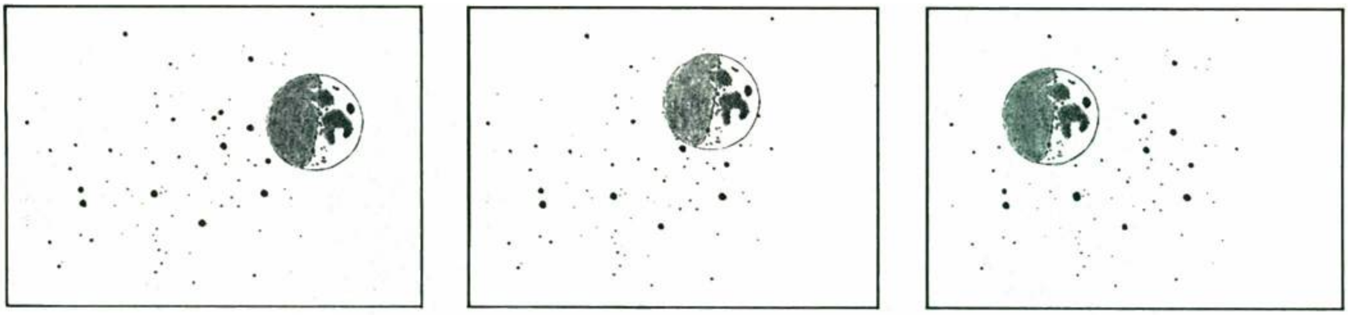
CAPTURED ON VIDEOTAPE, the corona's delicate rays and streamers are visible in this photograph made from the town of General Santos in the Philippines.



TWO STUNNING PROMINENCES, an enormous loop at upper right and a hedgerow-shaped prominence at lower left, were visible at mid-totality. These photographs were made from Bangka Island, Indonesia, but observers all along the path of totality said they will remember this as the "eclipse with the wonderful prominences." Enlargements of a photograph made with the same telescope (above) show the prominences in greater detail.



SPECTRUM OF THE CHROMOSPHERE made at second contact shows various emission lines in the Sun's spectrum. These bright lines are produced by certain elements (labeled). The photograph was made by placing a diffraction grating in front of a normal camera lens.



HIDING STARS AS IT GOES, the Moon passes in front of the Pleiades star cluster in Taurus in this series of sketches made on the evening of February 24, 1988. Observers throughout North America saw stars in the Pleiades cluster disappear behind the Moon's dark limb and reappear from the bright limb throughout the evening. From left to right the sketches show the occultation at 8:57 p.m., 9:47 p.m., and 11:18 p.m. EST on the 24th.

Thirty seconds before totality I could see sunset colors along the southern horizon. I don't remember seeing those so early at any other eclipse. The diamond ring at second contact lasted about fifteen seconds, the longest of any I've seen before. Two great prominences were easy to see with the naked eye.

"With a minute or so left a cloud bank reached the Sun. We could still see the corona through the clouds, and the prominences were accentuated considerably. Third contact was visible through the clouds. Shortly afterward the Sun disappeared into thick clouds and was rarely visible after that. At that point we all felt extremely lucky."

MOON OCCULTS PLEIADES STAR CLUSTER

On February 23, 1988, the First Quarter Moon passed in front of the Pleiades star cluster in Taurus, occulting many of the group's bright, blue-white stars. The situation was perfect for skywatchers in North America, who saw the Moon and the Pleiades high in the sky during the entire event. Only 46 percent of the Moon was illuminated during the occultation. The Moon's unlit side, faintly glowing by Earthshine, was the first to cross the cluster. This made it easy to see stars disappear one by one as the dark limb of the Moon covered them up.

In Jeffersontown, Kentucky, Larry McHenry of the Louisville Astronomical Society made a series of drawings of the occultation with a 3-inch refractor. Because he wanted to make a series of sketches showing the entire occultation, McHenry sketched the Pleiades and the Moon prior to the occultation. He photocopied the sketches and during the occultation noted the Moon's position relative to stars in the cluster on each photocopied sketch. The day after the occultation he glued cutout drawings of the Moon onto the Pleiades sketches, positioning the Moon at precisely the right spots and angles on each of the nine sketches. The resulting series shows the Moon's path across the starry field containing the Pleiades.

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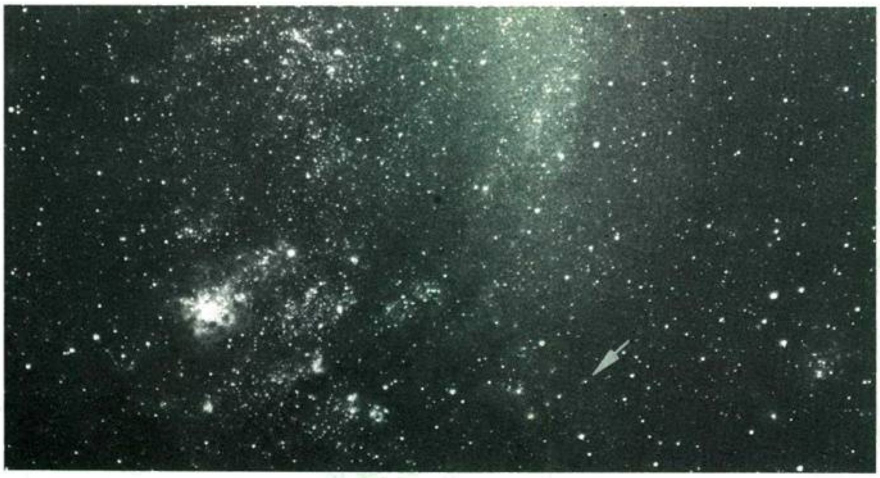

A DYING STAR GLOWS in this photograph of the Large Magellanic Cloud. Shortly after the nova (arrow) was discovered by Australian Gordon Garradd on March 21, 1988, it shone at 11th magnitude. Over the next two weeks the nova faded to 12th magnitude.

NOVA DISCOVERED IN THE LARGE MAGELLANIC CLOUD

A nova patrol coordinated by amateur astronomer Gordon Garradd of New South Wales, Australia, and professional astronomer Robert McNaught of Siding Spring Observatory has identified a nova in the Large Magellanic Cloud. The object is the third nova in the Magellanic Clouds discovered by Garradd and McNaught in the past eighteen months.

According to Garradd, "A star of magnitude 11.4 was found on two exposures taken on March 21, 1988. A comparison negative made on March 18 showed no image [in the nova's location] brighter than magnitude 15. As usual I was using a 300mm f/4.5 lens and hypersensitized Tech Pan film."

Garradd described the discovery: "The night of March 21 started off disastrously. After driving sixty kilometers west of Tamworth to one of my dark sky observing sites, I noticed I had left the hypered Tech Pan film back at home. I had to choose between visual observing where I was or photography in my moderately light-polluted backyard. I went home and set up the photographic rig.

"I took two photos of the Large Magellanic Cloud before it sank into light pollution. After checking a few galaxies for supernovae and doing a little comet searching with my binoculars, I went to sleep about 11 p.m. The next morning I developed and inspected the negatives. After five minutes of searching I found an 11th-magnitude star about a degree from supernova 1987A in the southeastern end of the galaxy's bar. I confirmed the object was a nova by checking that no star was at this position in the excellent atlas *The Large Magellanic Cloud* by Paul Hodge and Frances Wright."

Backyard observers and photographers interested in aiding Garradd and McNaught in patrolling the Magellanic Clouds should write to P.O. Box 157, Tamworth, New South Wales, 2340, Australia.

— David J. Eicher

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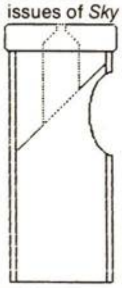

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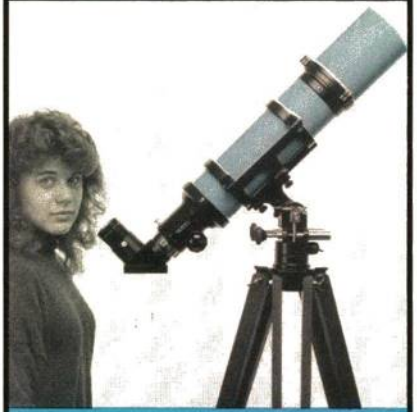

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I now own a massive, state-of-the-art 10-inch light bucket. But as wonderful as this sophisticated telescope is, I'll never forget the little telescope that first opened the universe to me when I was fourteen.

Because I couldn't afford an expensive, high-quality telescope, I chose a 60mm refractor that cost $89.95. (Today that same scope costs $179.95 in the same catalog.) I was quite careful about making my choice. I learned to take magnification boasts with a grain of salt, and I chose a telescope from a mail-order house that dealt in optics covered by a guarantee.

After three months of cutting grass and trimming hedges to earn the money for the scope and an additional two-week wait for the order to be filled, I took my tiny new refractor out under the semidark sky of a small city park.

Except for the Big Dipper and the North Star, I had little idea of where to find celestial bodies. My first night of observing can be best described as a shot in the dark. About the only discovery I made was that stars are just points of light in a telescope. If it hadn't been for the appearance of the Moon later in the evening, I might have considered the whole experience boring and banished the little telescope to the attic to collect dust.

After a couple of rainy nights, I toted the telescope back to the park. It was on this night that my casual fling with astronomy turned into a passionate affair.

Because I had used those rainy nights to get acquainted with a star chart, I was no longer a stranger to the night sky. I easily located Alcor and Mizar, the double star system in Ursa Major, but that was just an appetizer to the feast that was to follow.

I focused my low-power eyepiece on an object that wasn't on my chart. It wasn't the familiar point of light I had expected. The curious object looked like a disk, but I didn't ascertain the object's nature until I boosted my small refractor to its highest useful magnification — which was about 90x — and gently focused.

My jaw dropped, and the hair on the back of my neck began to rise. "My God," I said to myself, "I'm looking at Saturn. It looks just the way it does in all the books."

I felt like Galileo, Newton, and Einstein all rolled into one. After spending about half an hour transfixed at the eyepiece, I went home and set up my telescope in the backyard to show my family what I had discovered. Within the week I had shown Saturn to all my aunts and uncles.

Although none of the following viewing sessions ever compared with that inaugural encounter with Saturn, my first

telescope introduced me to even more spectacular wonders of the night sky. During the following winter I was able to follow the four major moons of Jupiter, and when seeing was excellent, I viewed changes in the Jovian cloud belts. I was also treated to the wispy spectacle of the Orion Nebula. The next fall I added the Andromeda Galaxy to my list of celestial ports of call.

As the years passed into decades, my interest in astronomy grew, and my need for more refined optical equipment followed. I purchased a high-quality 3.1-inch equatorial refractor and later a 10-inch telescope. With these telescopes I have continued my exploration of the night sky, but I owe my lifelong interest in astronomy to that first little telescope and the delights it showed me.

— Robert W. McCune

THE MYSTERY STARS IN SAGITTARIUS

I enjoy tracking down lost stars. It's detective work, delving into the history of astronomy to find the clues that help me figure out how a star got lost.

The mystery of the stars in Sagittarius began when I noticed that the star 1 Sagittarii was listed in *Sky Catalogue 2000.0* and in the catalog's "Index to Bayer and Flamsteed Designations." In the Becvar and Tirion atlases this star is labeled 11 Sagittarii and there is no reference to 1 Sagittarii, so I figured the listing in *Sky Catalogue* was a typographical error.

I told the editors of *Sky Catalogue 2000.0* about the error. They acknowledged that 1 Sagittarii should be listed as 11 Sagittarii and noted that the original 1 Sagittarii was probably located somewhere to the west in Ophiuchus after the International Astronomical Union established definitive constellation boundaries in 1930.

I was quite pleased with myself for having corrected this error, but finding the error made me wonder what happened to 1 Sagittarii. Why had the original 1 Sagittarii, cataloged by John Flamsteed, the first astronomer royal, disappeared?

I examined Flamsteed's *Catalogus Britannicus* of 1725 for clues, but the position listed for 1 Sagittarii doesn't correspond to any star in modern star atlases. Did Flamsteed make a mistake in listing the star's position?

I then consulted Francis Baily's *Account of the Reverend John Flamsteed* (1835), which included an annotated edition of the astronomer royal's catalogs, and *The Catalogue of Stars of the British Associa-*

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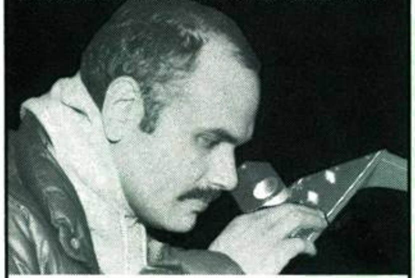

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ANNOUNCEMENT — MARS Amateur Astronomy Club in Tampa meets every second Thursday of the month at 7 p.m. in the Museum of Science and Industry. For more information contact Emilio Toro, 7407 Del Bonita Court 69, Tampa, FL 33617. Phone (813) 985-9289.

ANNOUNCEMENT — Amateur astronomy clubs in North and South Carolina are in the process of publishing a Carolina-wide newsletter, "The Carolina NGC." The newsletter seeks to establish a network of amateurs in the area to share in the joys of amateur astronomy. For more information contact Carolina NGC, 825 Ivywood Drive, Shelby, NC 28150.

ANNOUNCEMENT — The South Plains Astronomy Club meets the third Thursday of each month at the Lubbock Garden and Arts Center, 4215 University, Lubbock, Texas. Monthly star parties. Exceptional dark sky site for members. Phone Gene Crites at (806) 794-7941.

ANNOUNCEMENT — At 9 p.m. on June 10 and 11 in Jefferson, Iowa, the Bell Tower Festival's annual "Starwatch" will be held. Bring your own telescope or look through one of ours. For more information please contact Andrew M. Sorenson, Route 4, Box 4A, Jefferson, IA 50129.

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tion for the Advancement of Science (1845), the famous *BAC*. These works revealed that Flamsteed had made four observations of 1 Sagittarii, but he had indeed erred in reducing the star's coordinates to epoch 1690.0, the epoch of his catalog. In fact, he made two errors — one in the star's right ascension and one in its declination. Consequently, the star's coordinates appeared in his *Catalogus Britannicus* as R.A. 258°13′, Dec. −25°42′50″, instead of the correct figures, as ascertained by Baily, of 268°13′ and −23°42′50″.

But taking this correction into account only seemed to complicate matters. Based on these revised coordinates, on precession, and on the star's relationship with neighboring stars, the position of 1 Sagittarii corresponded precisely to where 11 Sagittarii is located on both the Becvar and Tirion atlases. How could this be? How could two stars occupy the same position? Was 1 Sagittarii synonymous with 11 Sagittarii?

The clues began to make sense after I compared the magnitude of 11 Sagittarii in modern catalogs with the star's magnitude in Flamsteed's catalog and the *BAC*. In both old catalogs 11 Sagittarii is listed as a 7th-magnitude star; in modern catalogs its magnitude is listed as 4.98. Though the concept of stellar magnitude has changed since Flamsteed's day, such a marked difference between two figures indicates we are dealing with two different stars.

Moreover, when I compared the position of the star Flamsteed designated 11 Sagittarii with positions of nearby stars and analyzed 11 Sagittarii's precession, I found that this star is actually HD 165921 with a magnitude of 7.28, which is very close to the value Flamsteed assigned to it. In other words, the star currently designated on stellar atlases as 11 Sagittarii (HD 166464) is not 11 Sagittarii but the original 1 Sagittarius, whereas the original 11 Sagittarii, a much fainter star, is a couple of minutes to the southwest in the diffuse nebula IC 4685.

It was difficult to retrace the steps that led to this mix-up, but apparently the "ones" in 1 and 11 Sagittarii have contributed to the confusion. Further complicating the problem is that 1 Sagittarii is not the lead star in right ascension in the constellation because of Flamsteed's error in reduction; instead it has been ignominiously pushed far to the rear between 11 and 12 Sagittarii (HD 166767).

Perhaps someday astronomers and celestial cartographers will restore 1 Sagittarii and 11 Sagittarii to their proper places in stellar atlases and catalogs.

— *Morton Wagman*

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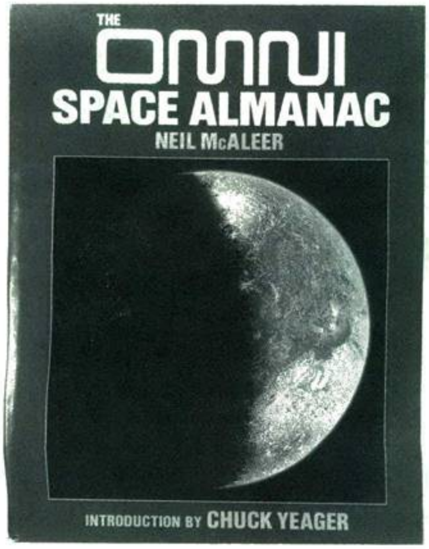
AN ALMOST COMPLETE GUIDE TO THE SPACE AGE

The OMNI Space Almanac by Neil McAleer, (Pharos Books, 1987), ISBN 0-88687-280-4, hardcover, 382 pages, $24.95.

If "almanac" means a chronicle of history to you, then only the first sixty pages of this book actually fit the title. Instead of an almanac, science writer Neil McAleer has compiled a scrapbook that gathers materials on several space-related topics. Despite the subtitle — it is not "a complete guide to the space age" — the book still manages to provide a lot of basic information about the U.S. space program.

It has twelve chapters. The first covers the golden age of the 1960s — *Mercury, Gemini,* and *Apollo* — and chapter two is on the shuttle. The third looks at proposed designs for the Space Station. Chapters four through six cover daily life in space (chiefly *Skylab* and the shuttle), close calls and disasters (including the *Challenger* accident), and "space international," a look at how other nations are getting into space either on their own or by purchasing rides on other countries' rockets. The development of the actual hardware is described in chapter seven, together with a look at what an advanced shuttle might resemble.

The unmanned programs, which have returned more science per dollar than anything else, are the subject of chapter eight. The author begins at the Sun, then he continues outward to Mercury, Venus, Mars, Jupiter, and so on, providing a summary of the missions to each of these objects and their results. I found this chapter to be one of the most interesting, because I have seen very few capsule histories that focus so concisely on the unmanned probes. It also maintains a more international viewpoint than the rest of the book.



Chapter nine discusses how commerce and science in space are going to open up new possibilities, new industries, new ideas, and so forth. The *other* justification for a space program finally surfaces in chapter ten: space weapons and wars. And not to end on that sour note, the book's last two chapters examine space colonies, Moon bases, and star flight (together with the requisite look at ETs). Two appendices (space organizations and museums) and an index conclude the book.

The OMNI Space Almanac is basically a narrative of events: there is little interpretation. While McAleer usually puts events into perspective, he doesn't editorialize. The main result is an archive of events; anyone is free to discover the theme(s) of these events.

As you'd expect from the people who brought you *OMNI* Magazine, known for its science fiction and science thought articles, projection of future developments is an important part of the book. Each chapter, for instance, includes a section on "where do we go from here?" Unfortunately, the near-future advances aren't very exciting and the really gripping projects don't look as if there is much chance of their happening in our lifetimes. If he's trying to sell us on space, McAleer's chief difficulty is that the path to the future is not as direct as it seemed only three years ago and that there is no agreed-on goal.

Despite NASA's fervent avowals that "the dream is alive," the dream died for some of us when it became clear that the *Apollo* program was a one-time freak and that the next grand step in space was firing a boxcar into low Earth orbit. The shuttle is a marvelous machine, but hardware interests me a lot less than where one travels in it. The Moon and planets have a fascination that the Space Station never will. And herein lies NASA's problem.

You can even track the changes in the agency's policies over the course of the book. When its funds were reduced in the early 1970s, NASA tried to build a constituency out of many groups pulling in different directions: the shuttle would do everything for everyone. As long as the pie was big enough, no real problems surfaced. But when the shuttle program began to devour dollars faster than anyone believed possible, NASA's "space coalition" began to break up like an Italian government.

The split runs right through agency headquarters itself, where a powerful contingent of manned flight advocates wants to keep flying people. Competing with this group is a group of space scientists, mostly outside NASA, who are lobbying for unmanned missions that come cheap in comparison to manned flights and that have created the entire field of planetary science almost by themselves. In the past the scientists loyally kept their disagreements over the agency's priorities inside the family, believing that open dissent would scuttle the whole thing. But facing a decade in which cost overruns with the Space Station and a reworked shuttle will appear regularly in the headlines, the scientists have begun to speak out publicly in the hope that this time unmanned space science won't be left out in the cold.

NASA, originally devoted to research and development, was irrevocably politicized at the start of the 1960s when Kennedy gave it the Moon mandate. But once its continued funding depended on keeping an ever-changing cast of politicians happy, NASA lost a lot of its freedom. Compromise is the name of the game in Washington, but in space it can kill people. Somehow NASA is going to have to preserve its engineering integrity *and* inspire grand dreams *and* convince politicians to fund its programs without stint — all while staying alive as an agency.

In dealing with the aftermath of the *Challenger* disaster, McAleer simply lays out the long-term difficulties that NASA faces but leaves the conclusions to us. All the same, any intelligent reader is left with a lot to think about. What *is* the shape of the future for the U.S. space program? McAleer doesn't say, but he provides his readers with enough recent history for them to make their own forecasts.

My biggest criticism is that this book focuses so strongly on the U.S. program that a casual reader might easily get the impression that the United States was the first into space and that the Russians were just tagalong latecomers. Although nods are given to the Soviet program here and there, McAleer basically ignores it.

A second complaint is that while *OMNI* Magazine is known in the industry for its lavishly funded production qualities, you'd never have guessed it from this book. All the photos are black and white and most look like bad reproductions of good color originals. Many are murky and some are out of focus; a few manage to be both.

The text is also saddled with often witless conversions into metric units. Not only is every customary unit converted, which is annoying in itself, but many times an obvious round number is calculator-translated into metric units without considering significant digits. To pick just one example, on page 164 we find 25,000 miles with (40,225 kilometers) faithfully tucked into parentheses right after. It would have been far better to convert only where it made sense and to keep the number of significant digits parallel.

Despite these criticisms, the book is certainly worth the price. It has a lot of text, and while it's impossible for any four hundred-page book to deal more than lightly with the events of the past quarter-century in space, McAleer does a good job despite the difficulties. Because depth must be sacrificed for coverage, anyone looking for lots of details on any specific mission is going to be disappointed. On the other hand, someone who wants a good summary of what's been done by the United States, together with a look at what we are planning to do by the turn of the century, will enjoy it very much.

— Robert Burnham

EIGHT SLIDE SETS FROM THE ASP

From time to time teachers and amateur astronomers call us at ASTRONOMY and request slides and background information on everything from planets to radio galaxies for use in the classroom or in public presentations. One of the first organizations we refer them to is the Astronomical Society of the Pacific, a nonprofit, educational organization based in San Francisco. The ASP has served as liaison between astronomers and the public for one hundred years. One of the ASP's specialties is offering astronomy educational materials at a nominal cost to schools, museums, and amateur astronomers. Materials offered by the ASP include videos, posters, and slide sets.

The number of slide sets offered by the ASP is considerable, and the topics are wide ranging — everything from astronomers of the past to the search for extraterrestrial intelligence. Below is a sampling, which includes a brief description of each slide set and the current price.

Astronomers of the Past. Drawing from public and private archives, this slide set portrays fifty noted astronomers of the past. The slides show astronomers as far back as Copernicus and Kepler and recent

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Lee Johnson, Coquitlam, B.C. Canada

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names such as Karl Jansky and Rudolph Minkowski. Fifty slides and a twenty-four-page booklet. $40.

Halley's Comet Revealed. This slide set offers the famous comet in some pretty poses, as well as showing the nuts and bolts of nucleus and tail dynamics. The set includes a schematic of the comet's nucleus, radio views of the comet, and ground-based and spacecraft photos. Seventeen slides and twenty-page booklet. $16.

The Infrared Universe: An IRAS *Gallery*. During its ten-month lifespan the *Infrared Astronomical Satellite* detected nearly a quarter of a million sources of infrared radiation. The twenty-five slides in this set show a sample of these objects. The accompanying fifteen-page booklet provides information about the spacecraft and its mission. $20.

The Radio Universe. Radio wavelengths can probe processes that cannot be seen at optical wavelengths, which makes this slide set one of the most intriguing from an astrophysical standpoint. However, the beauty and detail captured in the various images make the secondary point that modern radio astronomy has come a long way since its beginnings in the early 1930s. The forty color and black-and-white slides come from the National Radio Astronomy Observatory, which operates the Very Large Array, a Y-shaped array of twenty-seven radio dishes located near Socorro, New Mexico. The set shows radio views of the Sun, planets, supernova remnants, the center of our Galaxy, radio galaxies with jets, quasars, and radio sources in our Galaxy. A twenty-two page booklet is included. $35.

Splendors of the Universe. Fifteen slides showcase the photographic work of astronomer David Malin of the Anglo-Australian Observatory at Siding Spring, Australia. This slide set might have more appropriately been titled, "Splendors in the Southern Hemisphere," because the photos show prominent southern sky objects. However, Northern Hemisphere observers will recognize many of these selections — the Trifid, the Horsehead, and the Orion nebulae, for example. Perhaps the most beautiful shots are the galaxies: Centaurus A and the spiral galaxy M83 and its close look-alike NGC 2997. A fourteen-page booklet by Malin is included. $17.

Telescopes of the World. This set offers fifty slides of the world's most important optical and radio telescopes. Also included are scenic shots of the observatories. The set comes with a thirty-page booklet describing each telescope, plus an overview of telescope basics. $40.

The Search for Extraterrestrial Intelligence. SETI pioneer Frank Drake assembled the twenty color and black-and-white slides for this recently released set. The images include the message plaque sent aboard *Pioneer 10* and *11*, the disk of dusty material surrounding the star Beta Pictoris, a graph showing how the radio spectrum of Earth might appear from Barnard's Star, radio telescopes used in Drake's 1960 search (Project Ozma), and the new, million-channel signal analyzer now being employed to look for extraterrestrial intelligence. A twenty-page booklet by Drake accompanies the slide set. $20.50

Worlds in Comparison. Another new set contains twenty slides comparing the Earth and its geologic features with those found on other planets. Slides depict such relationships as the size of the Earth compared to that of Jupiter and of Saturn, the length of Manhattan Island in relation to the diameters of the Martian moons Phobos and Deimos, and the length of the Valles Marineris canyon complex compared to the width of the United States. $22.50.

In addition to these slide sets the ASP also offers Mars and Venus "kits" (each $11.50 set includes six slides and a booklet) and a supernova 1987A slide set (which includes six slides and a booklet for $10.50). If you're interested in a free catalog of ASP slide sets and other materials or just want more information, contact the ASP at 390 Ashton Avenue, San Francisco, CA 94112.

— *Jeff Kanipe*

ASTROPHYSICS

Low Temperature Detectors for Neutrinos and Dark Matter, edited by K. Pretzl, N. Schmitz, and L. Stodolsky, (Springer-Verlag, 1987), ISBN 3-540-18303-5, hardcover, 159 pages, $39.

COSMOLOGY

Dark Matter in the Universe, edited by J. Kormendy and G. R. Knapp, (D. Reidel, 1987), ISBN 90-277-2356-7, hardcover, 596 pages, $104.

The Early Universe, edited by W. G. Unruh and G. W. Semenoff, (D. Reidel, 1987), ISBN 90-277-2619-1, hardcover, 421 pages, $89.

GALAXIES

Structure and Dynamics of Elliptical Galaxies, edited by Tim de Zeeuw, (D. Reidel, 1987), ISBN 90-277-2585-3, hardcover, 579 pages, $89.

Meetings and Events

June 10-11
Front Range Star Party, Pawnee National Grasslands, Colorado. Sponsored by the Boulder Valley Amateur Astronomers and the Denver, Southern Colorado, Colorado Springs, and Cheyenne astronomical societies. Contact: Robert E. Stencel, University of Colorado at Boulder, Center for Astrophysics and Space Astronomy, Duane Physics, Room C-333, Campus Box 391, Boulder, CO 80309-0391. Phone: (303) 492-4050.

June 17-19
13th Annual Association des Groupes d'Astronomes Amateurs Congress, Sainte-Foy, Quebec, Canada. Sponsored by the Royal Astronomical Society of Canada — Quebec Centre. Contact: Royal Astronomical Society of Canada — Quebec Centre, P.O. Box 9396, Sainte-Foy, Quebec, Canada G1V 4B5. Phone: (418) 626-9592.

June 18
25th Annual Ohio Turnpike Astronomers Association Convention, Hiram College, Hiram, Ohio. Hosted by the Cuyahoga Astronomical Association of Cleveland. Contact: Robert Fritz, Cuyahoga Astronomical Association, P.O. Box 29089, Parma, OH 44129. Phone: (216) 237-3620.

June 25-26
The Universe in the Classroom, University of Victoria, Victoria, British Columbia, Canada. Weekend credit workshop on teaching astronomy in grades 3-12 for U.S. and Canadian teachers, sponsored by the Astronomical Society of the Pacific and the Royal Astronomical Society of Canada. Contact: Teachers Workshop, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.

June 25-July 3
100th Annual Meeting of the Astronomical Society of the Pacific, jointly sponsored by the Royal Astronomical Society of Canada and the Western Amateur Astronomers, University of Victoria, Victoria, British Columbia, Canada. Contact: A.S.P., Summer Meeting Department, 1290 24th Avenue, San Francisco, CA 94122.

July 8-10
6th Annual Festival d'Astronomie Populaire du Mont Megantic, Notre-Dame-des-Bois, Quebec, Canada. Conferences by professional astronomers, public observing on 1.6-meter telescope, and exhibits. Contact: Bernard Malenfant, President, 22, rang St. Pierre, Notre-Dame-des-Bois, Quebec, Canada J0B 2E0. Phone: (819) 888-2755 (days), (819) 888-2822 (evenings).

July 16-17
19th NFCAAA Summer Seminar, Syracuse, New York. Talks and contests sponsored by the Syracuse Astronomical Society. Contact: Frank Rioux, Summer Seminar, Syracuse Astronomical Society, 1115 Colvin Street, Syracuse, NY 13210. Phone: (315) 455-1003.

July 27-30
ALCON, the 1988 Astronomical League Convention, jointly sponsored by the Association of Lunar and Planetary Observers, Iowa Western Community College, near Omaha/Council Bluffs, Nebraska. Contact: George E. Allen, 3390 South 130th Street, Omaha, NE 68144. Phone: (402) 333-1097.

July 27-30
The Teaching of Astronomy, Williams College, Williamstown, Massachusetts. Colloquium sponsored by the International Astronomical Union. Contact: Jay M. Pasachoff, Department of Astronomy, Williams College, Williamstown, MA 01267.

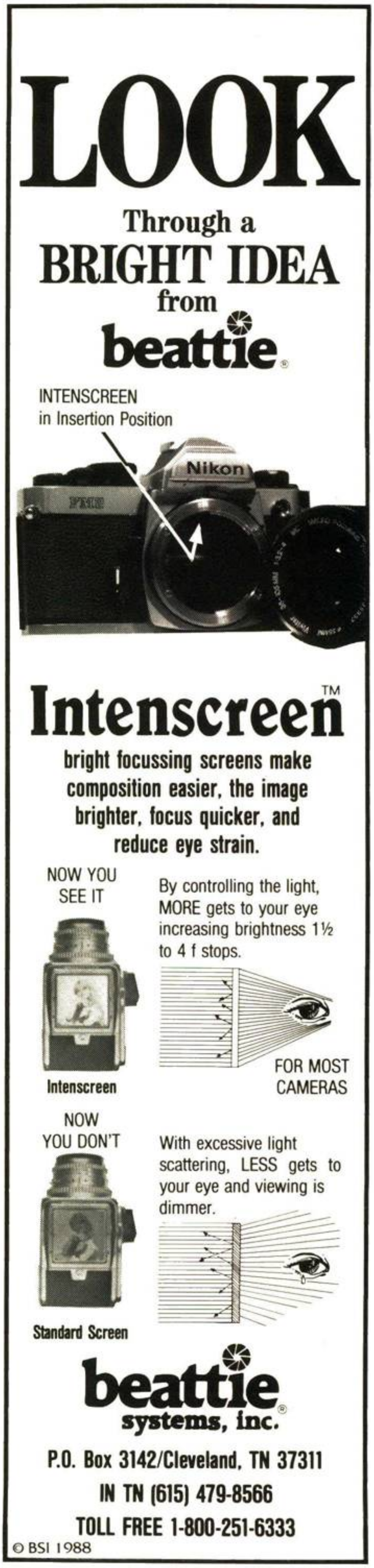
August 5-6
Starfest '88, River Place Campground, north of Mount Forest, Ontario, Canada. Sponsored by the North York Astronomical Association. Contact: North York Astronomical Association, 16 Beaufield Avenue, Toronto, Ontario, Canada M4G 3R3.

August 5-6
"War of the Worlds" Mars Symposium, Roper Mountain Science Center, Greenville, South Carolina. Special guests: ALPO Mars Recorders Jeff Beish and Don Parker; observing on the Daniel Observatory's recently dedicated 23-inch Clark refractor. Contact: Doug Gegen, Roper Mountain Science Center, 504 Roper Mountain Road, Greenville, SC 29615-4229. Phone: (803) 297-0232.

August 10-14
5th Annual Mount Kobau Star Party, Okanagan Valley, British Columbia, Canada. Telescope-making and astrophotography contests, observing, and speakers. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

Submit announcements at least four months before the date of the meeting or event.

When you write organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information.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Readings and Resources

Planetary Bombardments (page 20)

Coon Mountain Controversies: Meteor Crater and the Development of Impact Theory by William Graves Hoyt, (University of Arizona Press, 1987). The story of how scientists came to realize the importance of impact craters.

"The Origin of the Moon" by Stuart Ross Taylor, *American Scientist*, September-October 1987. A detailed examination of the impact origin of the Moon.

Cosmic Jets (page 30)

"Cosmic Jets" by Roger D. Blandford, Mitchell C. Begelman, and Martin J. Rees, *Scientific American*, May 1982. A readable technical explanation of the physical activity of large- and small-scale jets.

The Invisible Universe Revealed by Gerrit L. Verschuur, (Springer-Verlag, 1987). A review of the field of radio astronomy over the last fifty years.

"M87: Describing the Indescribable" by Jeff Kanipe, ASTRONOMY, May 1987. A detailed look at the M87 galaxy as well as the jet.

Soviet Space Missions (page 36)

"A Reporter at Large: Explorers" by Henry S. F. Cooper, Jr., *The New Yorker*, March 7, 1988. A behind-the-scenes look at the Soviet space establishment.

Computerized Dobsonians (page 71)

Almanac for Computers 1987, (Nautical Almanac Office, U.S. Naval Observatory, Washington, DC 20390, 1987). Equations for writing your own coordinate conversion program.

Sistiko model surveyor's compass similar to the Suunto model (below) but larger and with easier-to-read numbers. Sold by Howard Sutton Co., 121 East 24th Street, New York, NY 10010; phone (212) 260-4820.

Suunto model KB-14/360R surveyor's compass with reciprocal reading dial and Suunto PM5-5/360PC inclinometer (also called a clinometer). Each instrument costs $55. Sold by Howard Sutton Co.

Astrophotographic Filters (page 78)

Astrophotography for the Amateur by Michael A. Covington, (Cambridge University Press, 1985). A general overview of astrophotography.

"Gaining Confidence with Piggyback Astrophotography" by Rick Dilsizian, ASTRONOMY, April 1987. How-to advice on getting started in piggyback astrophotography.

Kodak Filters for Scientific and Technical Uses, (Eastman Kodak Company, 1981). Technical information about Kodak filters and their physical, optical, and transmission characteristics.

CREDITS

Cover: Jacques Guertin (f/19 Quantum 6 telescope operating at a focal length of 2900mm, Kodachrome 64 film, 1/15-second exposure); *page 4*: Huguette Guertin (700mm f/8 Questar telephoto lens, VRG 100 film, top and bottom at 1/125-second exposure, middle at 1/4-second exposure); *pages 10 and 12*: the European Southern Observatory; *page 14*: Jim Baumgardt (6-inch f/4 telescope, Tech Pan 2415 film); *page 16*: Elliott Moore, NASA/Joint Observatory for Cometary Research; *pages 20-21*: NASA Lunar Orbiter IV, Leon J. Kosofsky, principal investigator, National Space Science Data Center; *page 22*: courtesy of Marlin E. Kipp, Sandia National Laboratories; *page 25, top*: NASA Lunar Orbiter III, *bottom*: NASA *Voyager 2* image; *pages 26-27*: illustration by Dick Skover; *page 30*: courtesy of Lick Observatory, University of California; *pages 31-33*: radio images, National Radio Astronomy Observatory/Associated Universities, Inc., computer simulations courtesy of Michael Norman and Philip Hardee, National Center for Supercomputing Applications; research supported by the National Science Foundation; *pages 36-37*: illustration by Michael Carroll; *pages 42, 43, and 45*: California Association for Research in Astronomy; *page 44*: Schott Glassworks; *page 67, top*: Andrew Steinbrecher, *bottom left*: Sally Maran, *bottom right*: Roger W. Tuthill; *page 68, top left*: James Ehmann, *top right*: Glenn Schneider (4-inch f/12 Nikon apochromatic refractor, Kodachrome 64 film, 1/15-second exposure), *bottom left*: Roger W. Tuthill, *bottom right*: Glenn Schneider; *pages 71 and 75*: Robert Bunge; *page 72*: diagram by Thomas L. Hunt; *page 77*: Leonard Martin/Lowell Observatory; *page 78*: Art Schmidt; *pages 79, 81, and 82*: Rick Dilsizian (hypered Tech Pan 2415 film, pages 79 and 81 with a 50mm f/2 lens, page 82 with a 200mm f/2.8 lens); *page 80*: filter transmission curve supplied by Rick Dilsizian, Tech Pan 2415 sensitivity curve provided by Kodak; *page 83*: filter transmission curves supplied by Rick Dilsizian and based on data taken with a Perkin-Elmer 575 UV-Vis Spectrophotometer; *page 84, top*: Huguette Guertin (700mm f/8 lens, VRG 100 negative film, 1/2-second exposure), *bottom*: Randy Attwood (Sony CCD-V5 video camera attached afocally to a 60mm refractor); *page 85, top and insets*: Glenn Schneider (4-inch f/12 refractor, Kodachrome 64 film, top at 1/60-second exposure, insets at 1/250-second exposure), *bottom*: Robert B. Slobins (140mm lens with diffraction grating, Fujichrome 400 film, 1/60-second exposure); *page 86*: Larry McHenry (80mm refractor at 26.5x and 41x); *page 88*: Gordon Garradd (300mm f/4.5 lens, hypersensitized Tech Pan film, 12-minute exposure); *page 90*: illustration by Bryan Peterson.

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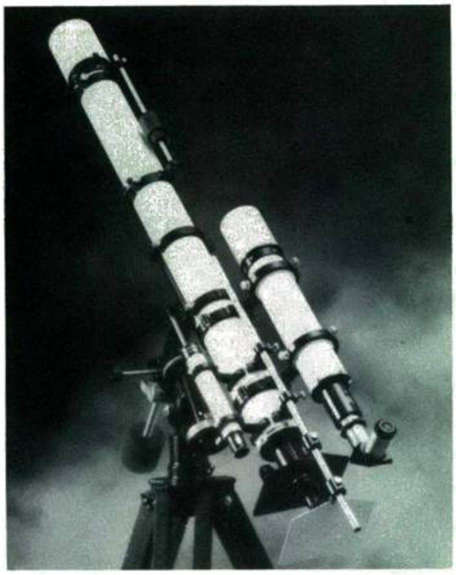

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FOR SALE — Meade 8" f/6 Newtonian with finder scope, 9mm and 25mm eyepieces, equatorial mount, setting circles, and clock drive. Excellent condition. $450 plus shipping. Contact Bill Bowne, 4528 Falcon Courts North, McGuire AFB, NJ 08641. Phone (609) 723-5041.

FOR SALE — Meade DS-10A, 280 PG guidescope with illuminated reticle, 8x50 R.A. finder, 2" prime focus adaptor, T-mount Canon, 47M drive corrector, on casters. $1,200 firm. Phone Roy Simpson (219) 264-2131 or (219) 264-7224.

FOR TRADE — PC JR computer with two keyboards, internal modem, operations manual, Wordstar, Procomm, and some games for C8 telescope. Contact Mark Edelson, 747 10th Avenue #26H, New York, NY 10019.

FOR TRADE — *The Large Magellanic Cloud* by Hodge and Wright, Smithsonian Astrophysical Observatory, 1967. Red slip cover, guide, and 163 maps. Extremely fine condition. Contact Joe Beelart, 1301 Quarry Court #108, Richmond, CA 94801. Phone (415) 232-3412.

FOR SALE — 4" Unitron refractor, complete with all accessories in three hardwood cases. Never used. $2,000 or best offer. Would consider 3" Questar in trade. Contact Phillip Edelstein, 2800 Winslow Avenue, Cincinnati, OH 45206. Phone (513) 961-5770 9 a.m. to 6 p.m.

FOR SALE — New Meade 2120/LX3 10" telescope, wedge, tripod, numerous accessories. $1,750. Contact Frank Olsen, 1513 Parkwood Lane NE, Cedar Rapids, IA 52402. Phone (319) 393-5758.

FOR SALE — Celestron Super C8 Plus with Starbright coatings, Tuthill Startrap power module, 8x50 finder, 26mm Plossl, 7mm orthoscopic oculars, wedge tripod, case, and several astronomy books. Excellent condition. $1,300. Contact Paul Ferriter, 33 Jones Court, Norwich, CT 06360. Phone (203) 886-1013.

WANTED — *Deep Sky* #1-#4, #6, #7, #11, and Winter 1986. Contact Chris Oliwa, 5/42 Palace Street, Ashfield, 2131, New South Wales, Australia.

WANTED — Correspondence with an amateur astronomer on an intermediate to advanced level. Also would like to buy a 6" to 10" reflector at a reasonable price. Equatorial mount preferred. Contact Jeremy Badger, 1000 Vassar, Wenatchee, WA 98801.

WANTED — Contact with anyone who has access to lunar orbiter or *Viking* images and images and information from interplanetary missions in general. Would also like correspondence with enthusiastic space supporters worldwide. Contact Ian Broadbent, 125 East Bawtry Road, Rotherham, South Yorkshire, England, S60 3LQ.

WANTED — Meteor photographers for the Upsilon Pegasid meteor shower. For free instructions send SASE to Hal Povenmire, 215 Osage Drive, Indian Harbour Beach, FL 32937.

WANTED — 4" refractor tube assembly. Celestron, Meade, Unitron, or other quality manufacturer. Phone (406) 232-5028.

WANTED — 12-1/2" f/6 reflector in east Texas area. Must be in very good condition. Contact Alan Keese, 2726 Shadowdale Drive, Houston, TX 77043. Phone (713) 556-3136.

WANTED — Any of Percival Lowell's books on Mars. Must be first editions. Please send all information on condition and price to Daniel Lorraine, 28 Priscilla Avenue, Providence, RI 02909.

WANTED — Amateur astronomer needs pen pals with same interest. Everyone write. I love everything to do with space. Fiction and fact. Please tell me if you believe in alien civilizations. Contact J. G., Route 6, Box 170, Searchy, AR 72143.

WANTED — 4" or 6" f/15 refractor objective, tube assembly parts, or complete tube assembly. Will also consider complete telescope with mounting. Send details to Shawn Mulcahey, 9927 Independence Avenue, Unit E, Chatsworth, CA 91311.

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Though astronomers are looking for a tenth planet, they're not even sure a tenth planet exists.

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WANTED — People interested in subscribing to an amateur astronomy newsletter. For information please write "Astronomers Gazette," 707 North Whispering Oak Circle, Powell, TN 37849. Or phone Adrian at (615) 947-0781 after 4 p.m. EST.

WANTED — Asaki Pentax K1000 camera, body only. Need not be in great shape as long as it's light-tight and the "B" setting works. Contact A. Burger, 259 Passaic Avenue, Passaic, NJ 07055. Phone (201) 473-4164.

WANTED — Correspondence with persons who use the ASTROSCAN. Share and compare techniques, experiences, best targets for observation. Contact Larry Richardson, 1617 Catalina Drive, San Angelo, TX 76901.

WANTED — Sixteen-year-old would like to correspond with other amateur astronomers. Contact Jackie Francis, 21599 Dolores Way NE, Aurora, OR 97002.

WANTED — Back issues of ASTRONOMY, *Sky & Telescope*, and other similar magazines (U.K. and U.S.A.). "Starlog," Future Life, Spacemen, and other movie/television science fiction magazines and comics. Also want science fiction movies (P.A.L. videos or Super 8mm). All items from the 1950s through the 1980s. Contact Ian Rowe, Box 1029, Garden City, Booragoon, Perth, Western Australia 6154.

WANTED — 4-1/4″ to 18″ refractors, Newtonian/-Dobsonian reflectors, cats, 2″ and 1-1/4″ eyepieces and accessories, large finders, copyscopes, equatorial mountings with drives (55-120mm), filters, quality supplies and parts, deep-sky binoculars, magazines, books, charts, and miscellaneous astronomical sundries. Prices must be reasonable. Forming a club — the Suffolk Amateur Astronomers. Contact Fortunato Comunale, P.O. Box D, 383 Birch Hollow Drive, Shirley, NY 11967. Phone (516) 399-2153.

WANTED — Meade 622 tube assembly in good condition. Contact Gene Schmidt, 12115 Lackland Road, Suite 257, St. Louis, MO 63146.

WANTED — Accutrack automatic star tracker system for astrophotography. Contact Joe Fedeli, 3291 Holme Avenue, Philadelphia, PA 19114. Phone (215) 443-1551.

WANTED — Jaegers complete clock drive unit for 1″ diameter shaft equatorial mount. Contact Karl Fabian, 3123 North Kenneth Avenue, Chicago, IL 60641.

WANTED — Pictures of the space shuttle *Discovery* or any other shuttle. Will pay or trade for them. Contact Jonathon H. Wilson, 380 Old Hollow Trail, Cohutta, GA 30710.

WANTED — Celestron Nova 8x50 binoculars. Contact Dawn Matter, 1027 Marshall Avenue, St. Paul Park, MN 55071. Phone (612) 459-0337.

WANTED — Twenty-six-year-old female with interest in space exploration and astronomy wishes to correspond with anyone, particularly those in the eastern states. Contact Daphne Burleson, 707A North Isabel, Glendale, CA 91206.

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Whether you're interested in studying Mars at close approach, dramatic Milky Way vistas, photography, or just having the most versatile scope handy, please seriously consider our refractors. They're designed for serious fun! Wishing you clear, dark skies. —*Al Nagler, Pres.*

Genesis

A 4″ aperture, 500mm, f/5 refractor is a prescription for a great rich-field telescope. But the unrivaled 5.4° wide angle view is just the beginning. The patented 4-element flat field design includes a fluorite crystal lens element to deliver superb resolution and apochromatic color-correction at powers from 9x to 260x. The fluorite lens is internally protected to eliminate sensitivity to moisture, shock, and thermal effects. Genesis weighs just 10 lbs. and is only 28″ long. It's the perfect synthesis of rich-field and long focus refractors, spotting scope and fast telephoto lens in one stunning instrument.

Oracle

The 3″ aperture, 560mm f/7.4 cemented triplet lens of the Oracle also delivers exquisite sharpness, contrast and apochromatic color-correction. This 6 lb. rugged telescope is ready to go anywhere you want, night or day. With a 5° field at 10x up to 200 plus power capability, it's the perfect choice in an even more compact scope—superior for the Pleiades as well as the planets.

No Other Telescopes Deliver All These Features:

Unsurpassed Sharpness Over the Greatest Power Range. Pinpoint star images across the field from edge to edge, from a vast 5° field at low power to over 250 power.

Superb Color Correction. Genesis and Oracle provide color correction far superior to "achromatic doublets." The fluorite lens in Genesis and cemented triplet in Oracle help achieve apochromatic performance.

High Contrast. The unobstructed design, proper blackening and multi-coatings all contribute to superb contrast, so essential for viewing planetary details, nebulae and galaxies.

Photographic Performance. Oracle and Genesis are sharp, fast telephoto lenses, terrestrial or astronomical.

Versatility. Excellent as long range microscopes, spotting scopes, finders, as well as for comet seeking, star clusters, galaxies, nebulae, double stars, planets, the moon and Milky Way.

Mountings. Standard photo tripods, or the rugged Tele Vue Panoramic Mount (shown with Oracle), can be used with both scopes for easy traveling. The Equatorial Systems Mount is great for tracking and features a full range of accessories for astrophotography.

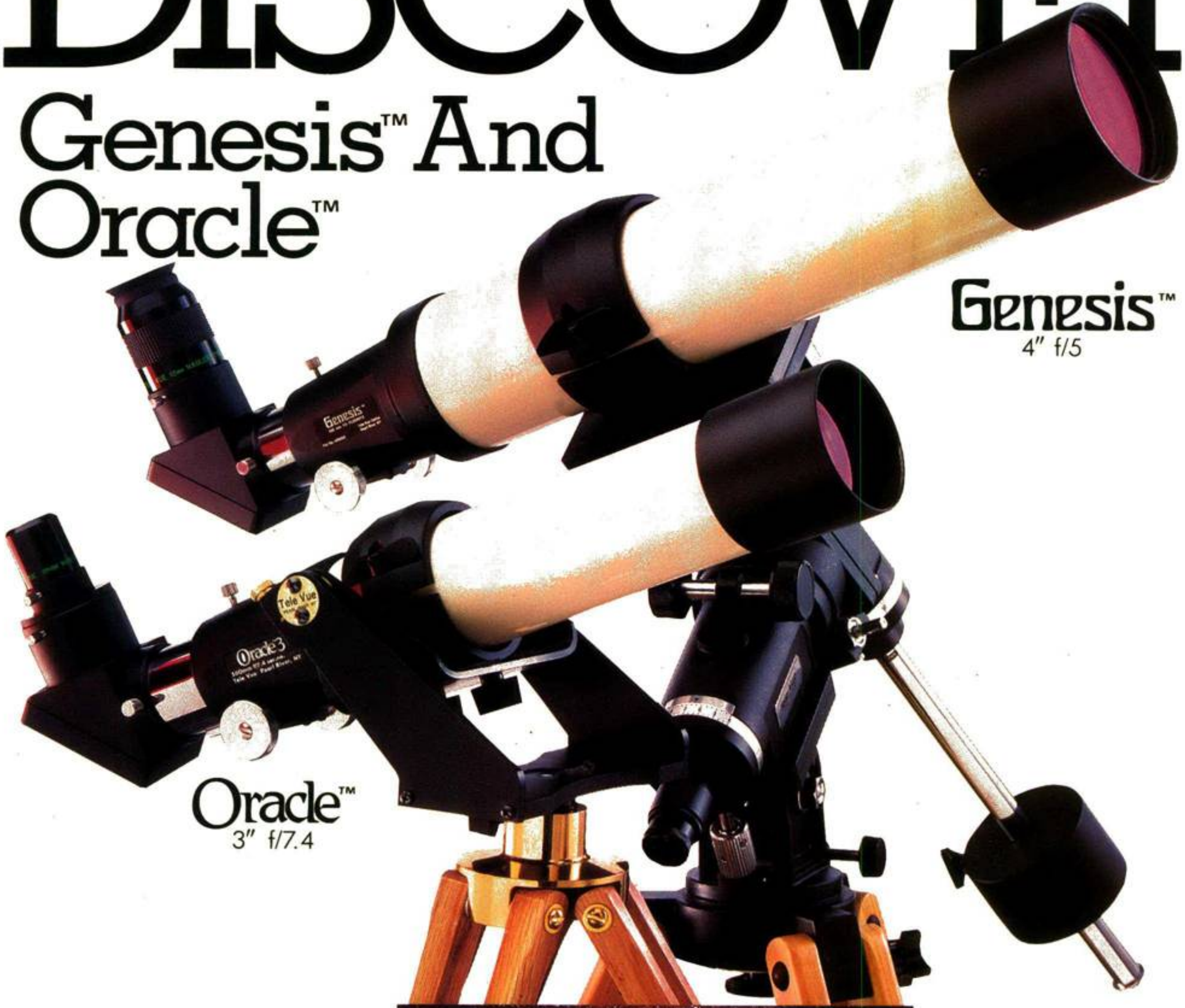
Tele Vue Eyepieces

"Use the best—Tele Vue. After all, the eyepiece is half the telescope," says Dr. Jack Marling. Fast scopes like Genesis and Oracle require the critical sharpness and high contrast of Tele Vue eyepieces. The reduction of astigmatism to improve sharpness across the field is recognized by patents on *all* Tele Vue eyepieces.

Richard Berry, editor of *Astronomy*, called our Plössls "the sharpest I've ever used." Our Wide-Field models represent a significant advance over Erfles, while our

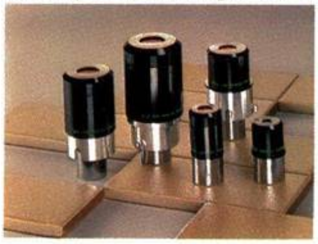
DISCOVER

Genesis™ And Oracle™



Nagler series is considered a landmark breakthrough. Pat Walker called the Naglers "a picture window with magnification." Even today, with fine imitations on the market, critical users will see better edge definition and *larger* apparent fields, regardless of competitive claims.

Tele Vue 50° Plössl, 65° Wide Field, and 82° Nagler eyepieces deliver all the quality inherent in Genesis and Oracle. For maximum performance and power, matched Tele Vue Barlow lenses extend the telescope's focal length 1.8 or 2.5 times. For the widest true field possible, use the 55mm Plössl (with optional new adjustable eyeguard). And consider Nagler Type 2 eyepieces for the ultimate in low and medium power wide-angle viewing, day or night.



Extraordinary Value

Genesis and Oracle are fully outfitted with these standard features: deluxe case with cutouts for eyepieces, screw-on metal cover and dew shield, 2" rack and pinion focusser with lock screw, 2" mirror-type star diagonal, 1¼" adapter, adjustable mounting ring and a 26mm Plössl.

Whether you're seeking superior sharpness, a more manageable companion to larger instruments, or the finest first telescope, Genesis and Oracle offer no-compromise choices! Send $1 for complete literature package.

Tele Vue™

20 Dexter Plaza, Pearl River, NY 10965
(914) 735-4044

Andromeda Galaxy - M31, SP-C6 Photo

Courtesy of Jim Riffle, Astro Works

CELESTRON UNFOLDS DEEP SKY WONDERS

With Celestron's premium quality diffraction limited SP-C6 and C4.5 Newtonian reflectors, you can explore the mysteries of deep space. Choose 4-1/2 or 6 inches of aperture with high quality multi-coated primary and secondary mirrors. A latitude scale, and slow motion controls and setting circles are included in both axes.

The SP-C6 comes standard with a Super Polaris equatorial mount. This deluxe, technically advanced German equatorial mount utilizes precision 144 tooth lapped worm gears in both axes. An adjustable counterweight makes it easy to point, balance and use. For easy set-up and operation, a built-in illuminated polar alignment scope is standard as is a unique slide focus system. The tripod has excellent vibration dampening characteristics.

The C4.5 is supplied with a high quality, yet economical, standard Polaris equatorial mount. The natural wood finish tripod is of fixed height and provides extra rigidity.

Add an optional single or dual axis stepping motor drive or Sky Sensor computer to the SP-C6 to make observing easier and high resolution astrophotography possible. For the C4.5, an optional single axis drive is available which functions as a fixed rate sidereal tracking unit.

Whichever reflector you choose to best suit your viewing needs, interests and budget, remember it is backed by Celestron's Lifetime Limited Warranty. For a reflector that's a sound investment—and an excellent buy for your dollar, see your Celestron dealer today.

For additional information, send $3.00 to:

CELESTRON®
CELESTRON INTERNATIONAL
2835 Columbia Street • Torrance, CA 90503 (USA)
Telephone (213) 328-9560, (800) 421-1526 (Continental USA)

Celestron's SP-C6 and C4.5 (shown left to right)